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Wrong-Way Driving (Phase II)

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16. ABSTRACT

At the end of 1964, the State Highway System of California included a total 1570 miles of full freeways and about 740 miles of expressways - access controlled, like the full freeway, but with many crossings still at grade.

These divided highways account for over one-half of the total vehicle miles of travel on the State Highway System. With the accelerated development of the multilane divided highway, new traffic problems have arisen. One of the most serious is that of the wrong-way driver- the one who somehow manages, in spite of warning messages, traffic islands, directional arrow signs and pavement markings, to drive down the highway in a direction opposing the normal traffic flow.

For the purpose of this study, wrong-way driving is defined as any vehicular movement in a direction opposing that of the legal flow of traffic on divided highways or on the connections providing entrance or exit to such highways.

The seriousness of the problem is indicated by some accident statistics. During the years of 1961 through 1964, there were 83 fatal wrong-way accidents on freeways which resulted in 126 deaths and an additional 150 injuries.

The study of wrong-way driving movements was initiated as one phase of a general study of highway safety under Chapter 2110, Highway Safety Research, authorized by the Legislative Session of 1961. The report of that study, known as Phase I, was published in January 1963*. This report concerns Phase II, a continuation of Phase I. The primary purpose of Phase II was to develop means of reducing the amount of wrong-way driving and more importantly, the number of accidents caused by wrong-way driving.

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STATE OF CALIFORNIA

HIGHWAY TRANSPORTATION AGENCY

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

TRAFFIC DEPARTMENT

WRONG-WAY

Project accomplished

with the cooperation of the

U.S. Bureau of Public Roads

FEBRUARY 1965

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
TRAFFIC DEPARTMENT

February 25, 1965

Mr. J. C. Womack
State Highway Engineer
Sacramento, California

Dear Sir:

Submitted herewith is a report on:

WRONG-WAY DRIVING

(Phase II)

Study under direction of	T. N. Tamburri
Project Engineer	D. J. Theobald
Project Assistant	A. J. Rice
Report prepared by	T. N. Tamburri and D. J. Theobald

Sincerely,

J. E. Wilson
Traffic Engineer

TNT/DJT:bd

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I. INTRODUCTION

At the end of 1964, the State Highway System of California included a total 1570 miles of full freeways and about 740 miles of expressways - access controlled, like the full freeway, but with many crossings still at grade.

These divided highways account for over one-half of the total vehicle miles of travel on the State Highway System. With the accelerated development of the multilane divided highway, new traffic problems have arisen. One of the most serious is that of the wrong-way driver - the one who somehow manages, in spite of warning messages, traffic islands, directional arrow signs and pavement markings, to drive down the highway in a direction opposing the normal traffic flow.

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known as Phase I, was published in January 1963*. This report concerns Phase II, a continuation of Phase I. The primary purpose of Phase II was to develop means of reducing the amount of wrong-way driving and more importantly, the number of accidents caused by wrong-way driving.

It is also planned to continue the study (Phase III) to determine the effectiveness of new signs and pavement markings and to learn more concerning the types of ramps and designs conducive to wrong-way driving.

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* C. V. Gay, "Wrong-Way Driving Incidents on Limited Access Divided Highways", January 1963, by California Division of Highways.

II. SUMMARY OF FINDINGS

1. During the four-year period of 1961 through 1964, there were an average of 20 fatal wrong-way accidents on freeways in which an average of 31 persons per year were killed.

2. Approximately 1200 wrong-way incidents were observed in 18 months, 763 on freeways, 354 on expressways and 97 on conventional roads.

3. Approximately one-third of all the wrong-way drivers had been drinking. Four-fifths of the fatal accident wrong-way drivers on freeways had been drinking.

4. The younger driver is primarily involved in "drinking" wrong-way driving.

5. The rate of wrong-way driving per vehicle miles of travel increases with age.

6. Approximately one-half of the freeway wrong-way driving originates at off-ramps and at expressway grade intersections.

7. White pavement arrows installed between the two studies have reduced the incident of daylight wrong-way entries at off-ramps and at expressway intersections.

8. Wrong-way incidents and accidents both tend to peak in the early morning hours. The increased drinking during these hours is a large factor in the increased "late hour" "wrong-way" driving. A secondary peak at midday caused primarily by older drivers was observed in the incidents.

9. As a result of testing in the Driving Simulation Laboratory of the Institute of Transportation and Traffic Engineering at the University of California at Los Angeles, new and revised signs and pavement markings are being installed at all off-ramps, on-ramps, transitions to freeways from undivided roads and expressways, and at expressway intersections.

10. Commercially available spring-loaded spike barriers were found to be ineffective in stopping vehicles. Modified spikes were effective in deflating tires within 10 to 30 seconds.

11. Preliminary testing of a special automatic device consisting of an illuminated sign ("GO BACK--YOU ARE GOING--WRONG WAY"), a 12" red light, two horns, and an amber flashing light indicates that this type of device may be effective in preventing wrong-way entry at off-ramps. Testing of this device is continuing.

III. SYNOPSIS

The problem of wrong-way driving on California freeways and expressways has been investigated in two separate studies. Results furnish information about the magnitude of wrong-way driving incidents, the origin of the wrong-way moves, age and sobriety of the drivers, time of day, and other details of the occurrences themselves.

Efforts to reduce the occurrences of wrong-way driving can be divided into two general areas:

1. Prevention of wrong-way movement.

   (A) Geometrics.

   It appears that some particular ramps, including the scissors or cul-de-sac type and diamond and hook connections adjacent to major street intersections, are susceptible to wrong-way movements. However, present information is not sufficient to conclude that this susceptibility applies to all ramps of these categories or to compare with other ramp categories.

   It is proposed to study in depth the geometrics of interchanges and the details of ramp terminal design and expressway intersection design.

   (B) Signing and Pavement Markings.

   These have been studied both in the laboratory and on the highway, and it is expected that Statewide measures now being taken to upgrade and supplement the existing signing and markings will significantly reduce wrong-way driving.

2. Detection, Warning, and Physical Restraint.

(A) Detection and Warning.

A warning device, consisting of an illuminated sign, lights and horns, all activated by a wrong-way vehicle, is being tested at one off-ramp. At this location, it has been effective in stopping the majority of wrong-way drivers.

It is proposed to test additional detectors, with counters and cameras, at various off-ramps throughout the State, to compare wrong-way driving at different types of ramps.

(B) Physical Restraint.

The last resort to prevent wrong-way driving is some degree of physical restraint. To be effective, a barrier must either disable a vehicle or remove it from the roadway. At the present time there is no known physical barrier that is both effective and safe. Parking lot type spike barriers have been tested and found to be inadequate. Detailed results of these tests are included in this report.

It is proposed to conduct a third phase of the wrong-way study to evaluate the new signs and markings by a third incident study, investigate ramp terminal design in detail, continue testing the automatic warning device, and continue to seek a feasible physical barrier.

IV. STUDY PROCEDURE

Data concerning wrong-way driving was obtained by several methods. The first was a special report (Figure 1) filled out by enforcement officers who patrol California freeways and expressways, each time a wrong-way driving incident was observed. During two separate nine-month periods, January to October in 1962 and from July 15, 1963 to April 15, 1964, the California Highway Patrol reported for those sections under their jurisdiction. During the latter period, the city police of Los Angeles, San Diego, Long Beach, and Riverside also reported for those freeways they patrol.

Results of the first nine month incident study were reported in January, 1963.* Comparison of results of the second incident study with the first were made and any differences are noted in this report. The effects of remedial action taken as a result of the first study were determined by these changes. Data from both studies were combined to provide a broader base of the problem for considerations of remedial action to be taken and to determine the effectiveness of any new devices or signs.

A second source of information for this study was the 1963 accident data of California freeways and expressways. On the site reconnaissance was made for several wrong-way fatal accidents. The California Highway Patrol provided additional information that is not a

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* C.V. Gay, "Wrong-Way Driving Incidents on Limited Access Divided Highways", January 1963, by California Division of Highways.

CALIFORNIA HIGHWAY PATROL
SACRAMENTO, CALIFORNIA

WRONG WAY DRIVING INCIDENT

Time 14:15 Date 3-25-62

Driver JOHN Q DRIVER

Driver's License No. N.I.P. Birthdate 6-1-30

Vehicle License No. SAM 123 Accident Report No. —

Violation 21653 V.C.

1. Driver stopped, traveling N (direction) on US ~~395~~ 395

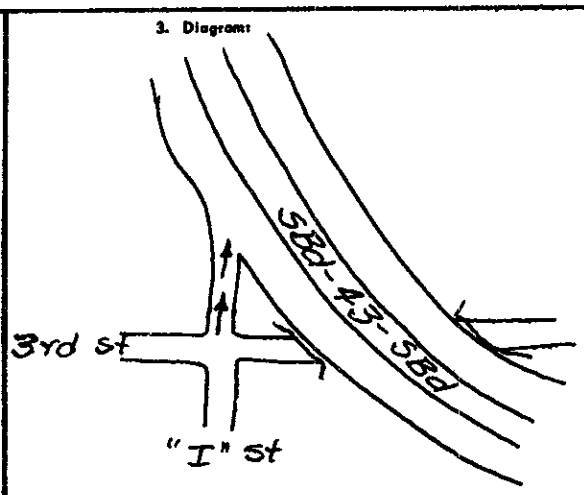
County SBD Leg. Route 43 Sect. SBD

approx. 1/4 miles N (direction) of 3rd St. overcrossing or crossroad.

2. Circle Appropriate Item Numbers

WEATHER	LIGHTING	SOBRIETY	TRAFFIC CONDITIONS
(1) Clear	(1) Daylight	1. HBD-obviously drunk	1. Light
2. Cloudy	2. Dusk or dawn	2. HBD-ability impaired	(2) Moderate
3. Raining	3. Dark-No St. Lt.	3. HBD-ability not impaired	3. Heavy
4. Snowing	4. Dark-St. Lt.	4. HBD-impairment unknown	ROADWAY USE
5. Fog		(5) Had not been drinking	1. Regularly
6. Other			2. Occasionally
			3. Rarely
			(4) Never before

3. Diagram:



4. Driver's Statements:

I didn't notice the signs.

5. Officer's Opinions:

I feel the driver was just day-dreaming since the signs are very obvious.

Officer's Name Bill Jones #701 Org.

Figure 1

regular part of the accident report.

Since primary objective of this study was to develop means of reducing the amount of wrong-way driving and more importantly, the number of accidents caused by wrong-way driving, the following was done:

1. Various sign messages and sign designs were tested in the Driving Simulation Laboratory of the Institute of Transportation and Traffic Engineering at the University of California at Los Angeles.

2. Full scale dynamic tests of spring loaded spike barriers were conducted.

3. An automatic device consisting of horns and lights activated by wrong-way vehicles was developed and tested.

V. WRONG-WAY DRIVING INCIDENTS

A. General

A total of 1117 special reports were received during the 18 months the two studies were in effect for freeway and expressway incidents of wrong-way driving. They are broken down as follows:

Study	Freeway	Expressway	Total
1962	312	187	499
1964	451	167	618
TOTAL	763	354	1117

An additional 97 conventional highway incidents in 1964 were received and coded in the second incident study bringing the grand total to 1214.

Not every blank on every form was completed so that in almost all statistical breakdowns of the data the 1117 items are not always accounted for.

Results of the tabulations* of the primary items on the form are as follows:

1. Time of day - see graph Figure 13 for distribution of time of day of incidents.

2. Month and year data is not included since the same months were not used for the two nine-month periods. Occurrence of incidents by day of the week are shown below.

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* (Except when stated otherwise, the 1214 freeway, expressway, and conventional highway incidents were used in the tabulations.)

	Number	%
Sunday	196	16.2
Monday	157	13.0
Tuesday	166	13.7
Wednesday	138	11.4
Thursday	189	15.6
Friday	165	13.6
Saturday	199	16.5
	1210	100%
Not Stated	4	
	1214	

3. Of the total 1214 incidents 971 (80.0%) involved male drivers; 242 (20.0%) were women; and in 11 incidents, sex was not stated.

4. Weather on the incident forms was coded as follows:

	Number	%
Clear	912	79.3
Cloudy	133	11.6
Raining	61	5.3
Snowing	5	0.4
Fog	35	3.0
Other	5	0.4
	1151	100%
Not Stated	63	
	1214	

5. Light condition on the incident reports was coded as follows:

	Number	%
Daylight	522	43.1
Dusk or Dawn	33	2.7
Dark - No Street Lights	385	31.8
Dark - Street Lights	271	22.4
	1211	100%
Not Stated	3	
	1214	

6. Sobriety on the freeway and expressway incident reports was coded as follows: (H.B.D. is the abbreviation for Had Been Drinking)

	Number	%
HBD - Obviously drunk	181	16.3
HBD - Ability impaired	65	5.8
HBD - Ability not impaired	135	12.1
HBD - Impairment unknown	44	4.0
Had not been drinking	688	61.8
Total	1112	100%
Not Stated	5	
	1117	

Over one-third (38.2%) of the wrong-way freeway and expressway drivers had been drinking.

7. Traffic conditions on the incident reports was coded as follows:

	Number	%
Light	507	44.3
Moderate	545	47.7
Heavy	91	8.0
Total Coded	1143	100%
Not Coded	71	
TOTAL	1214	

Although traffic condition is only a relative index depending on the location of the highway, the fact that only eight per cent occurred in heavy traffic is worth noting.

8. Roadway use on the 1964 incident reports was coded as follows: (this item not recorded in 1962 study)

	(a) No.	(b) % of total	(c) % of each group in Column (a) who H.B.D.*
Regularly	146	25.0	53.7
Occasionally	132	22.6	39.4
Rarely	158	27.1	32.3
Never Before	148	25.3	26.4
Total	584	100%	46.9
Not Coded	130		
Total	714		

*H.B.D. = Had been drinking

9. In 600 (80.5%) of 745 interpretable freeway incidents, (18 unknown), the wrong-way driver was stopped on the freeway lanes. Only 145 (19.5%) of the wrong-way drivers were apprehended at the ramp or interchange.

B. Drivers' Age and Sobriety

Table I shows the amount of wrong-way driving by drivers' age. By introducing the number of registered drivers in each age group and the average miles driven by age group, a relative index of the tendency to drive the wrong way based on amount of travel exposure was determined and shown in Table I. As was also stated in the previous report on wrong-way driving, the amount of wrong-way driving based on vehicle-miles of travel increases with driver age.

The index illustrates that the younger drivers have the best relative wrong-way driving record. A moderate increase is evident at the 30-39 and 40 to 49 age groups. Over 60 the index rises rapidly, and over 70 the index is approximately 10 times higher than the 16 to 29 age groups.

The mean age of male wrong-way drivers is 47.3 years. For females the mean age is 48.6 years. Both mean ages are approximately the same as found in the first study.

Approximately one-third (36.7%) of all (freeway, expressway, and conventional) wrong-way drivers had been drinking (See Table II). This is slightly higher than in the first report (31.5%).

Drinking as a contributing cause of wrong-way driving increases to a maximum in the 30-39 age group where 58.9% of the drivers had been drinking, and then drops off to a low in the over 70 age group where 58% of the drivers had been drinking. Only in the 30-39 age group was the "had been drinking" offenders greater in number than the sober wrong-way drivers.

TABLE I

WRONG WAY INCIDENTS BY AGE GROUPS

(Freeways and Expressways)

Age Group	Wrong-Way Driving Incidents: Freeways No.	Freeways %	Expressway No.	Expressway %	Total Controlled Access No.	Total Controlled Access %	Reg'd.* Drivers %	% WW / % Reg'd.	Average* Annual Mileage Driven	Ratio Adjustment Factor to 10,400 Mile Average	Ratio % WW / Exposure
16 - 20	27	3.6	12	3.4	39	3.6	9.3	0.39	9,100	1.14	0.44
21 - 24	49	6.6	10	2.9	59	5.4	9.0	0.60	9,600	1.08	0.65
25 - 29	49	6.6	22	6.3	71	6.4	11.3	0.57	10,800	0.96	0.55
30 - 39	151	20.2	58	16.6	209	19.1	22.6	0.85	10,800	0.96	0.82
40 - 49	153	20.5	77	22.0	230	20.9	21.4	0.98	10,450	1.00	0.98
50 - 59	129	17.3	68	19.4	197	18.0	14.5	1.24	10,100	1.03	1.28
60 - 69	101	13.5	61	17.4	162	14.7	8.1	1.81	8,600	1.22	2.21
70 & over	88	11.7	42	12.0	130	11.8	3.8	3.11	6,300	1.65	5.13
	747	100.0%	350	100.0%	1097	100.0%	100.0%	Average	10,400		
Age Unknown	16		4		20						
Total	763		354		1117						

* Research & Statistics Section, California Department of Motor Vehicles

TABLE II

SOBRIETY BY AGE GROUPS
All Incidents

Age Group	Drunk or Ability Impaired		All Groups of H. B. D.		Sober		Percent of Group that H. B. D.
	No.	%	No.	%	No.	%	
16 - 29	31	12.7	65	15.2	122	16.4	34.6
30 - 39	77	31.6	133	31.0	93	12.5	58.9
40 - 49	72	29.5	118	27.6	119	16.0	49.8
50 - 59	50	20.5	82	19.2	128	17.3	39.1
60 - 69	11	4.5	22	5.1	151	20.4	12.7
70 & over	3	1.2	8	1.9	129	17.4	5.8
	244	100%	428	100%	742	100%	36.7
Not Stated	9		16		28		
	253		444		770		

H. B. D. - "Had been drinking"

The mean age of "had been drinking drivers" is 41.8 years. The mean age for sober wrong-way drivers is 50.9 years.

Figure 2 graphically illustrates some of the relationships shown in Tables I and II.

C. The Locale of Wrong-Way Driving

Wrong-way driving takes place on both high volume urban freeways and low volume rural freeways and expressways.

On high traffic volume urban freeways, the large number of vehicles provide good and frequent clues to the wrong-way driver that he is doing something wrong. However, these same high volumes (and the median barriers) make it difficult to take corrective action. Since urban freeways are generally more heavily patrolled, wrong-way incidents are more likely to be detected.

In rural areas, large gaps in traffic flow allow easier wrong-way entry, fewer clues from moving vehicles of the correct direction of flow but greater opportunities for corrective measures once the driver realizes his error.

Table III lists the twenty counties with the most incidents in order of descending number. These are all the incidents reported in both studies on freeways, expressways, and conventional divided highways.

Los Angeles County accounts for the largest per cent of the travel in California and ranks second on this list. Although Tulare County is almost entirely rural and it has considerably less travel than Contra Costa, Alameda or San Mateo Counties, it ranks fourth on the list and it

WRONG-WAY DRIVING BY AGE GROUP

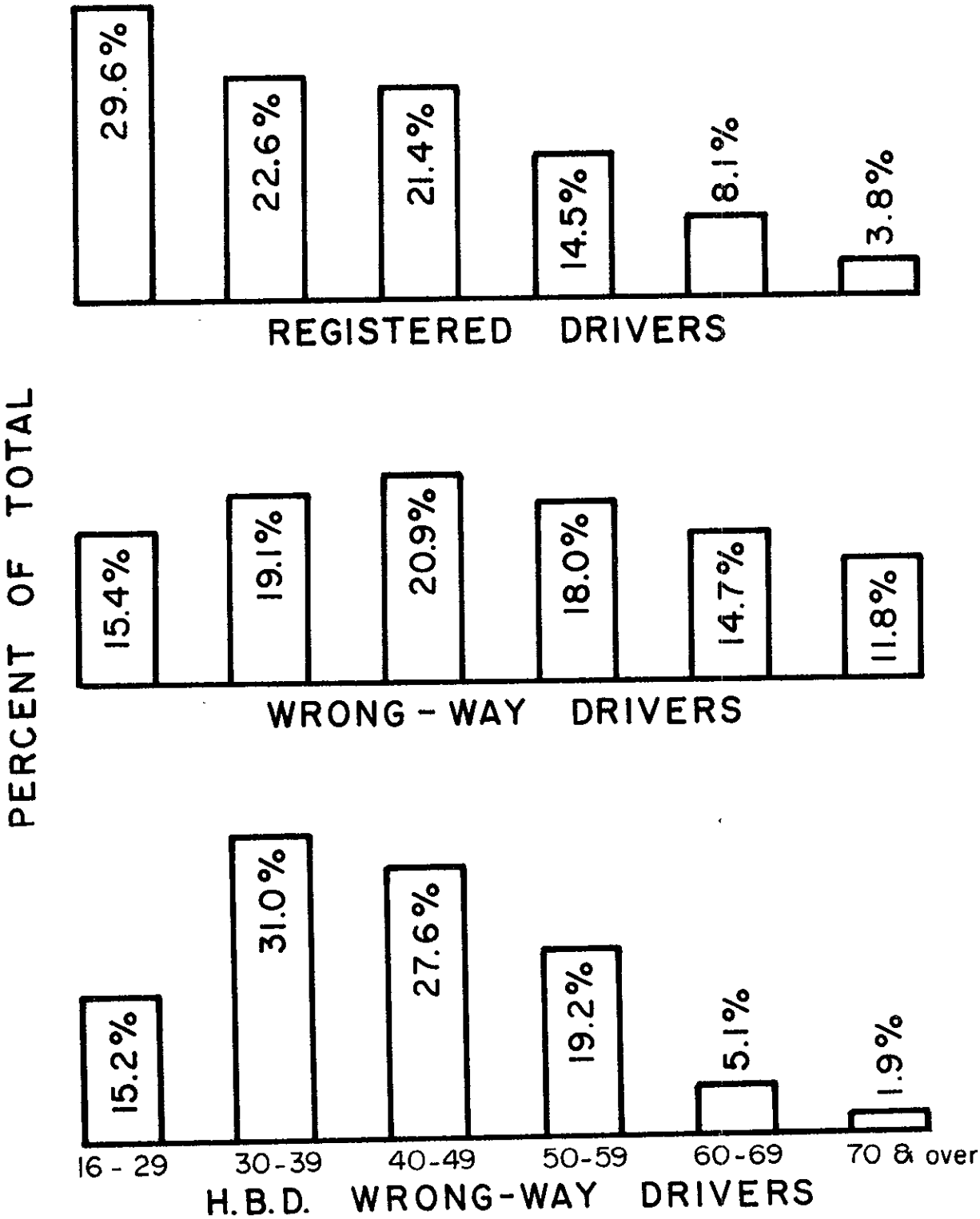

Figure 2

TABLE III

TOP TWENTY COUNTIES
All Incidents

		*Total Incidents	1964 Fwy Travel (MVM)	% Entered Via Off-ramp	% Over 70 age	% H.B.D.
1.	San Bernardino	133	972	36.1	16.5	27.9
2.	Los Angeles	132	8,236	32.6	6.0	42.5
3.	Riverside	114	480	20.2	17.5	21.9
4.	Tulare	55	305	14.5	12.7	40.0
5.	Ventura	54	238	16.7	13.0	29.6
6.	Solano	52	282	25.0	7.7	40.4
7.	Santa Barbara	51	200	11.7	3.9	25.5
8.	Santa Clara	39	665	18.0	18.0	28.2
9.	Sacramento	38	494	60.5	10.5	63.2
10.	Contra Costa	38	535	39.5	10.5	55.2
11.	San Diego	35	1,102	48.5	8.6	54.3
12.	Kern	34	300	11.8	5.9	26.5
13.	San Luis Obispo	33	118	18.2	27.2	18.2
14.	Fresno	32	202	31.2	6.3	40.6
15.	Alameda	32	1,503	21.9	18.7	43.8
16.	Sonoma	30	197	30.0	13.3	53.3
17.	Monterey	27	78	0	25.9	14.8
18.	San Mateo	26	926	42.3	0	73.0
19.	Merced	24	87	16.7	8.3	37.5
20.	Orange	23	999	34.8	8.7	34.8
Average				27.0	11.9	36.2

*Includes freeway, expressway and conventional roads of both incident studies.

has considerably more wrong-way driving incidents than the latter three counties.

It is noteworthy that San Francisco and Marin Counties are not in the top twenty. All the freeways in San Francisco and most of the freeways in Marin County have high volumes. These high volumes may be acting as a deterrent to wrong-way driving.

As a means of further comparison of these top twenty counties, Table III also lists by counties the percentages of the wrong-way drivers who (1) entered via off-ramp, (2) were over 70, and (3) had been drinking.

Counties with the larger freeway mileage and travel naturally tend to have high percentages of entry via off-ramps.

San Mateo County ranks first in the percentage of wrong-way drivers who had been drinking. Sacramento, Contra Costa, and Sonoma Counties then follow in that order. In a previous study* a high incidence of accidents involving drinking drivers was noted on San Mateo County freeways.

The two counties with the highest percentages in the over 70 wrong-way driver age category (Monterey and San Louis Obispo) had the smallest percentage of the drivers who had been drinking.

D. Origin of Freeway Wrong-Way Driving

The initiating maneuver or origin of wrong-way driving on freeways for both the 1962 and 1964 studies are

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*J. Vostrez & R. Lundy, "Comparative Freeway Study" April, 1964, (page 37) by California Division of Highways

TABLE IV

ORIGIN OF WRONG-WAY INCIDENTS (FREEWAYS)

	CHP REPORTED 1964 Study		CITIES REPORTED 1964 Study		COMBINED 1964 Study		CHP REPORTED 1962 Study		TOTALS All Studies	
	No.	%	No.	%	No.	%	No.	%	No.	%
Entered Fwy via off-ramp	137	45.6	28	70.0	165	48.5	146	58.2	311	52.7
Made U-turn from off-ramp (right-way on freeway)	12	4.0	2	5.0	14	4.1	4	1.6	18	3.0
Made U-turn from on-ramp (wrong-way on freeway)	37	12.3	1	2.5	38	11.2	16	6.4	54	9.1
Made U-turn into on-ramp (right-way on freeway)	25	8.3	0	0.0	25	7.4	9	3.6	34	5.8
Made U-turn in traffic lanes	67	22.3	4	10.0	71	20.9	43	17.1	114	19.3
Drove across median divider	13	4.3	4	10.0	17	5.0	5	2.0	22	3.7
Other U-turns on on- or off-ramps	9	3.0	1	2.5	10	2.9	28	11.1	38	6.4
	300	100%	40	100%	340	100%	251	100%	591	100%
Maneuver Unknown	88		23		111		61		172	
Total Incidents	388		63		451		312		763	

shown in Table IV. In the "1962" column, there are some minor discrepancies with data given in the 1963 report. This is the result of some revising of the classifications of some of the 1962 incident reports during the 1964 analysis.

There has been a 24% increase in the number of incidents reported (312 in 1962 and 388 in 1964) on the freeways patrolled by the California Highway Patrol. The increase in travel on CHP patrolled freeways is greater than 24%.

The number of freeway wrong-way driving incidents which originated at off-ramps, however, decreased slightly in the 1964 study (137 incidents) compared to the 1962 study (146 incidents). This reduction occurred in spite of the large over-all increase in the total number of freeway incidents and the large increase in freeway travel and number of off-ramps. It is believed that a corresponding increase in the number of off-ramp originating incidents did not occur because white pavement arrows were painted on all off-ramps in the interim between the two incident studies.

A more detailed analysis of the incidents originating at off-ramps (Table V-A) shows that there was a moderate (83 to 88) increase in number of incidents occurring at night while the number of daytime incidents decreased substantially (63 to 49). The decrease in daytime off-ramp originating incidents was <u>not</u> a part of a general decrease in daylight incidents. By referring to Table V-B, it can be seen the daylight incidents originating

TABLE V-A

LIGHT CONDITION - ENTERED FREEWAY VIA OFF-RAMP

Light Condition	CHP Reported 1962 Study		CHP Reported 1964 Study		% Change
	No.	%	No.	%	
Daylight	63	43.1	49	35.8	-22
Dawn or Dusk	5	3.4	7	5.1	+40
Dark - No Street Lights	49	33.6	37	27.0	-24
Dark - Street Lights	29	19.9	44	32.1	+52
(Total "Dark")	(83)	(56.9)	(88)	(64.2)	+ 6
TOTAL	146	100%	137	100%	- 6

TABLE V-B

LIGHT CONDITION - ENTERED FREEWAY BY OTHER THAN OFF-RAMP

Light Condition	CHP Reported 1962 Study		CHP Reported 1964 Study		% Change
	No.	%	No.	%	
Daylight	61	58.1	83	50.9	+ 36
Dawn or Dusk	4	3.8	5	3.1	+ 20
Dark - No Street Lights	26	24.8	40	24.5	+ 54
Dark - Street Lights	14	13.3	35	21.5	+150
(Total "Dark")	(40)	(38.1)	(75)	(46.0)	(+ 88)
Total Origin by Other than Off-ramp	105	100%	163	100%	+ 55
Origin Via Off-ramp	146		137		
Origin Unknown	61		88		
Total	312		388		

at locations other than off-ramp actually increased a substantial amount, rising a total of 22 from 61 to 83.

Since the entire improvement occurred during the daylight, it might be assumed that white pavement arrows painted on asphalt concrete surfacing are more visible in the daylight than in the dark. However, another explanation might be that the white arrows are not being seen by the drinking drivers who, in the main, are on the road at night. This is substantiated by the fact that approximately 50 to 70% of the nighttime off-ramp incident drivers had been drinking compared to an overall average of only 36.7% "drinking" incidents. (See Table below.)

Had Been Drinking - "Dark" Incidents

Origin	1962 Study CHP Patrolled			1964 Study CHP Patrolled		
	HBD	Total	%HBD	HBD	Total	%HBD
Off-Ramps	40	83	48.2	61	88	69.3

As shown in the table below, almost two-thirds of drinking drivers originate their wrong-way driving at the off-ramp while less than half of sober wrong-way drivers start at this location. Drinking drivers tend to use the most direct path to their desired direction of travel on the main highway. Sober drivers make U-turns as often as they use the off-ramp.

Point of Origin	Had Been Drinking		Sober	
	No.	%	No.	%
Off-ramp	130	63.4	181	46.9
Various U-turns	69	33.7	189	48.9
X-median	6	2.9	16	4.2
Total	205	100%	386	100%

The fact that there has been no reduction in the number of nighttime wrong-way driving incidents originating at off-ramps, points up the need for developing arrows, signs or devices with more visibility and impact to reach the tired or the drinking driver.

E. Types of Off-Ramps

From a designer's viewpoint, one of the most important benefits of this study would be definite information on the type of off-ramps most commonly used by wrong-way drivers. Some knowledge of what geometric features or combinations of features are conducive to wrong-way entry is, therefore, highly desirable.

Many of the drivers in the older group and the group who had been drinking had no idea whatsoever where they initially started their wrong-way trip. Even when they knew the interchange they had used, there usually were two or more different paths that could have been taken. Even the sober, alert drivers were somewhat confused or they would not be going the wrong-way.

Intentional wrong-way driving (when the driver should be able to reconstruct his route) was mostly confined to taking short cuts. A typical freeway short cut is made by the driver who misses the off-ramp at an interchange and makes a U-turn into the on-ramp to reach his desired crossroad.

Only when the arresting officer witnessed the incident, was an exact determination of wrong-way driving origin possible. Sometimes the direction of travel and the location of entry onto the freeway made the isolation of one

particular off-ramp possible. In the other cases, the best judgment of the researcher was used when a probably offending ramp was indicated. Where no possible clues were present, the point of entry was classified "unknown".

Table VI then is a compilation of the data after the above qualifications are applied. The ramp classes shown in the table are defined as follows:

Diamond - A ramp of fairly good alignment usually terminating at a two-way cross road and with provision for turning right or left at the crossroad. The right turn (or direct connecting) ramps at cloverleaf interchanges were also included. (Figures 3 and 4)

Loop (Full Cloverleaf) - A one-way small radius ramp of approximately 270° for left turning movements located at interchanges with four such facilities (Figure 4).

Loop (Two Quadrant Cloverleaf) - The same as above except at interchanges with only two such facilities. Usually, both left and right turns are provided at the crossroad termini of these ramps. (Figure 5).

Buttonhook - Buttonhook ramps (Figure 6) have small radius curves of approximately 90° and terminate at a local road parallel to the freeway. Some of the ramp pairs (on-and-off) in this category are an integral portion of a full interchange with a freeway crossing and others are isolated pairs without a closeby facility for the reverse movements.

Trumpet - The ramps, both left and right turning, at 3-leg interchanges (Figure 7).

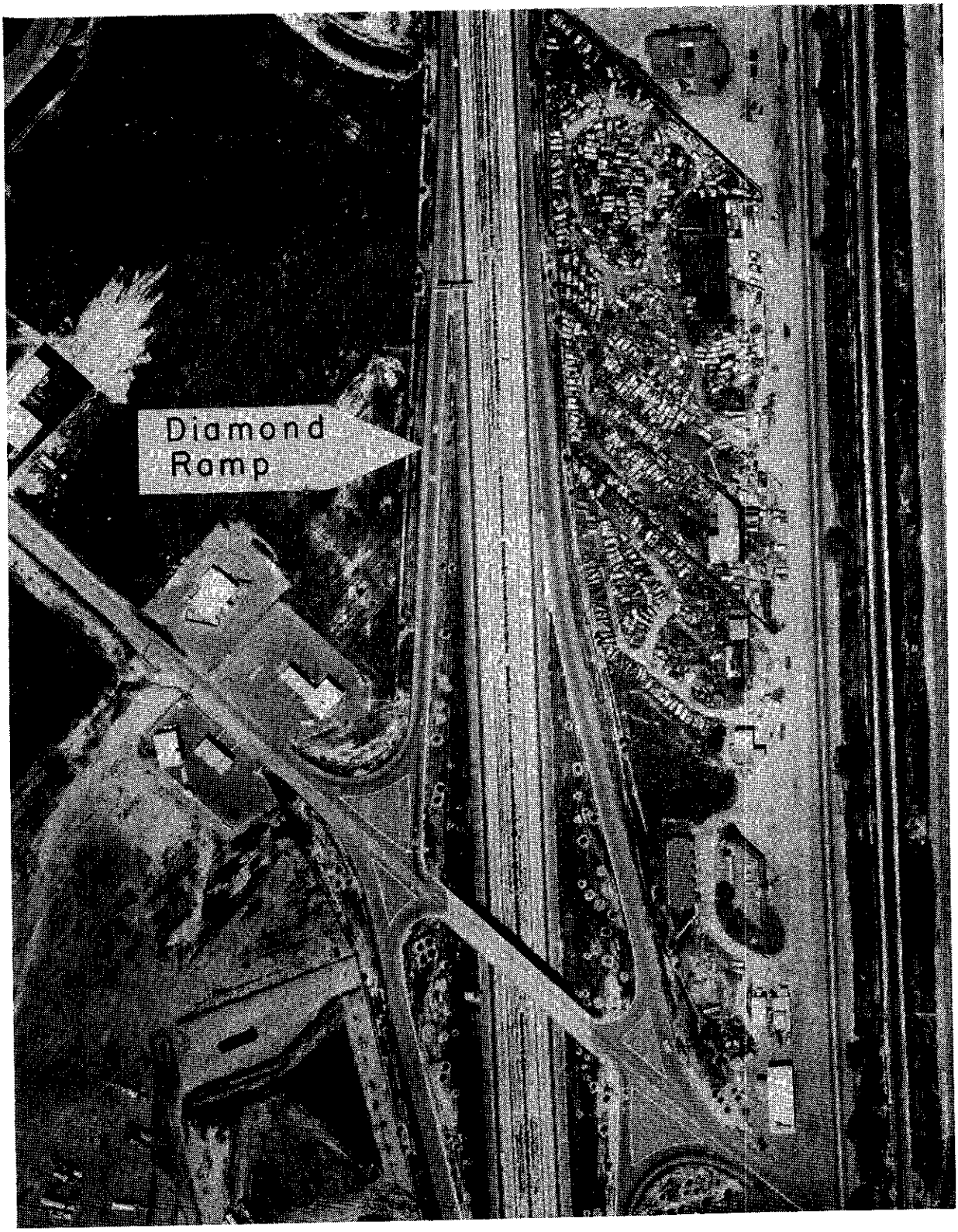


Figure 3

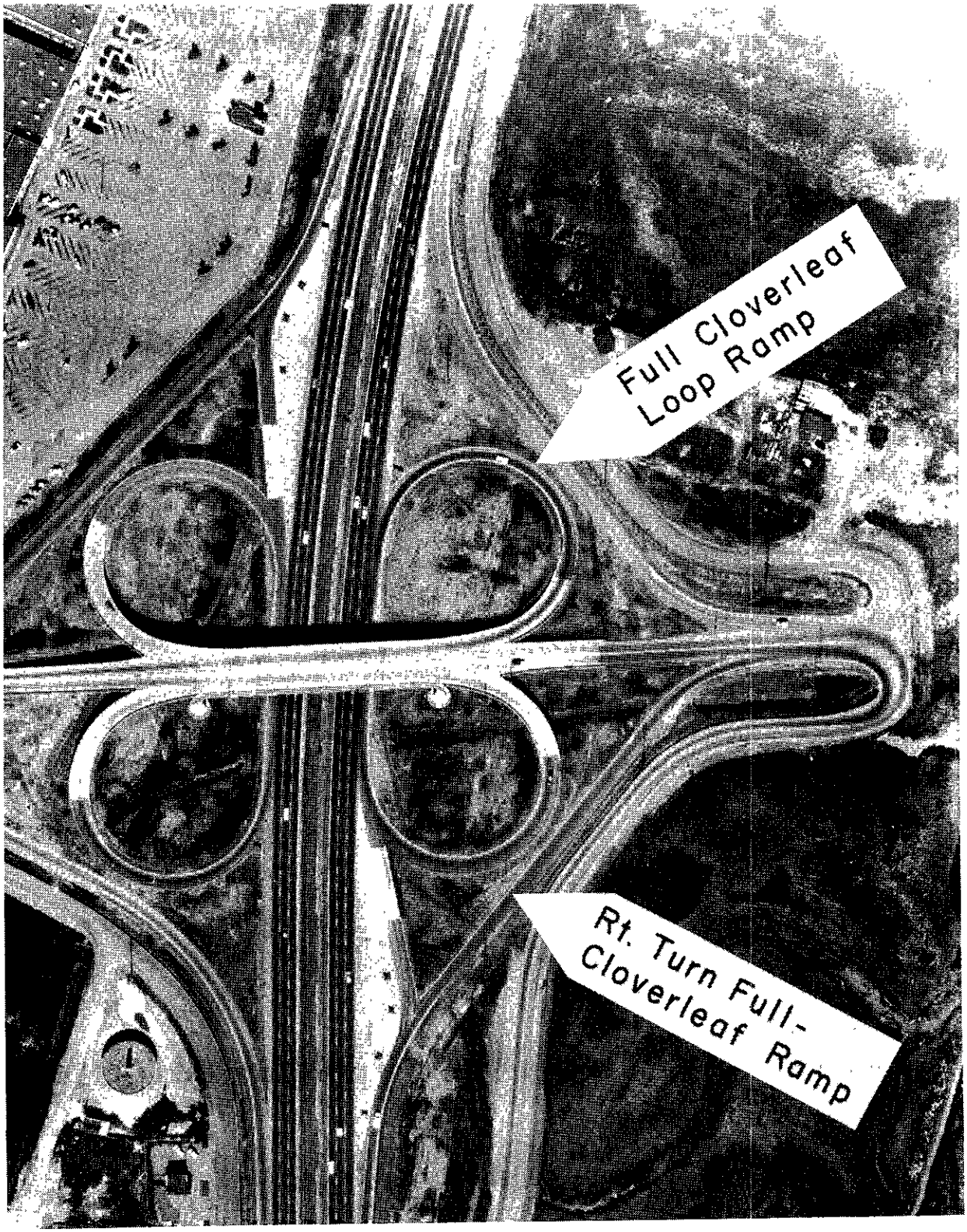
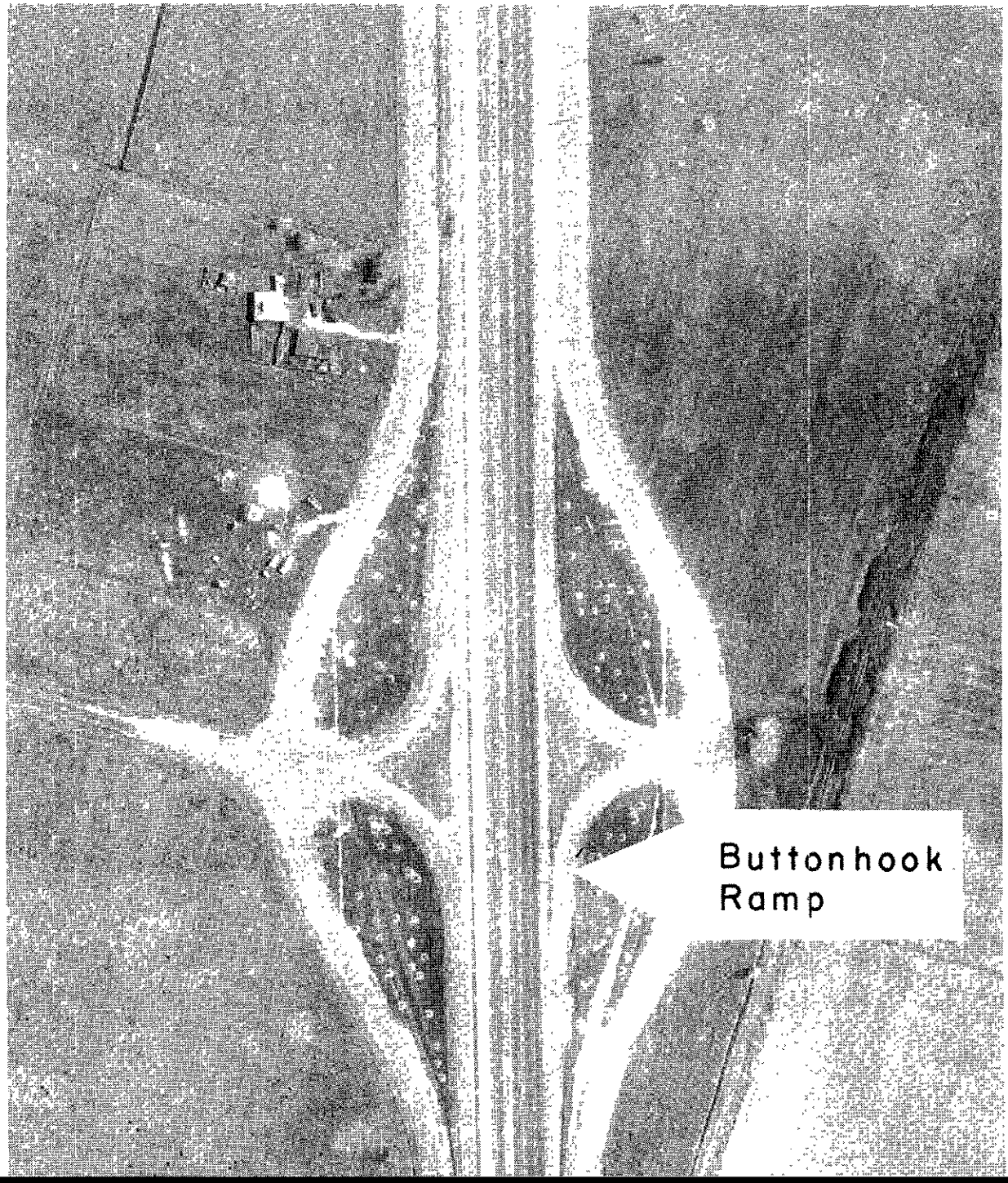


Figure 4

Figure 5



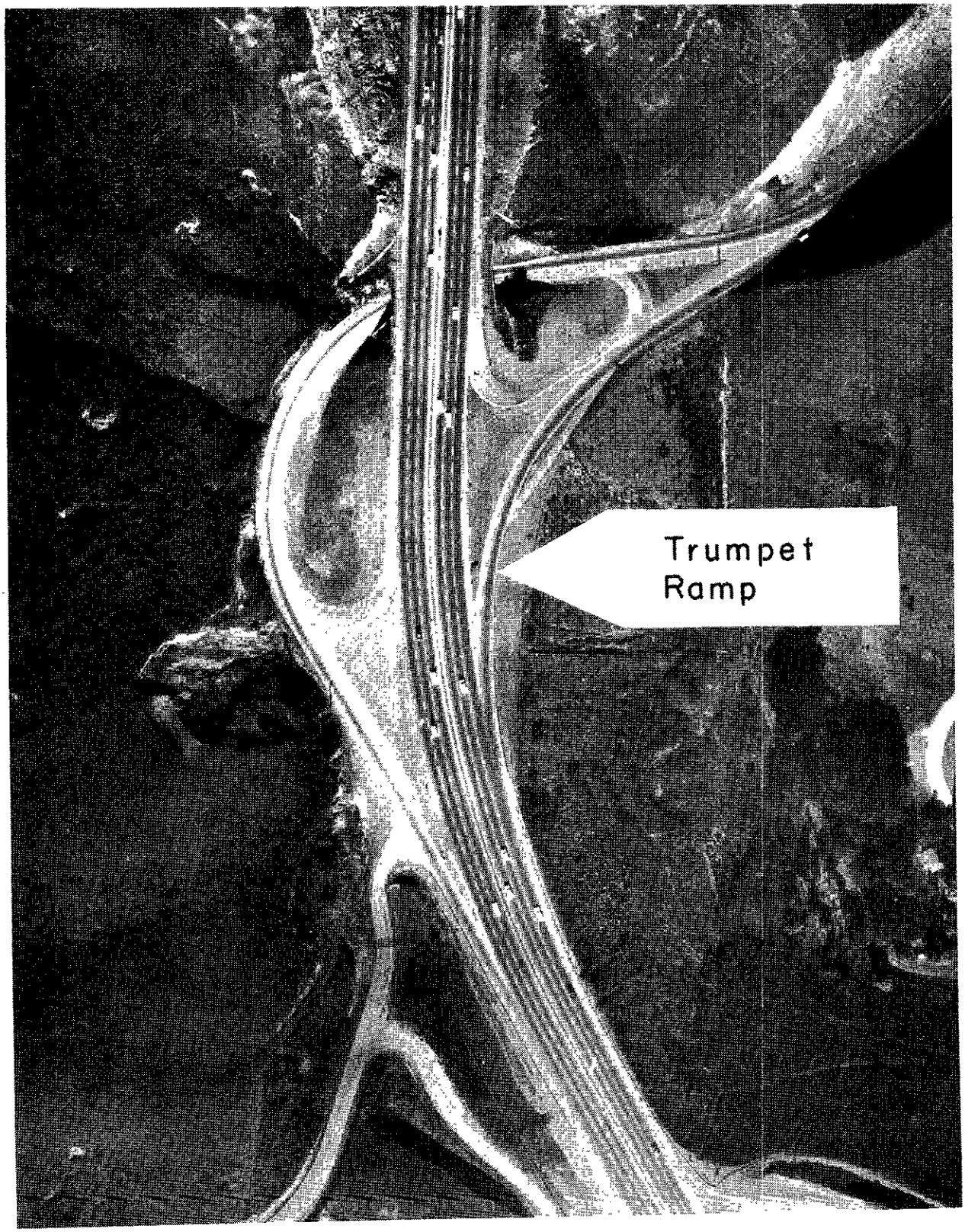


Figure 7

Cul-de-Sac or Scissors - An off-ramp whose geometric design allows direct and preferential alignment across opposing traffic of a two-way parallel road. Traffic on the two way road which is opposite to the flow on the off-ramp is usually channelized to cross the off-ramp traffic at approximately 90°. (Figures 8 and 9).

Unclassified - Unclassified ramp types were all those that did not fit any of the standard named interchange types. Many were direct connections between intersecting freeways. The number (96) that fell into this category illustrates the difficulty of getting clear cut classifications as to ramp design.

The ramp type most frequently used as the origin of wrong-way driving is the diamond (including the right turning ramp of cloverleaf interchanges). Approximately one-third (37.5%) of all off-ramp originating incidents were traced to this ramp type. This is the most common ramp type.

Figures 10 and 11 illustrate various wrong-way movements originating at ramps.

No attempt was made to obtain a classified inventory of ramp types. This will be done in Phase III to correlate wrong-way driving to ramp type and ramp terminal design details. As part of this future study, it is also planned to obtain surveillance data at a number of each ramp type using portable directional detectors and movie cameras to record wrong-way ramp entries. The frequency of wrong-way entry will be related to ramp type, ramp and cross-road geometry and signing, and ramp and freeway traffic

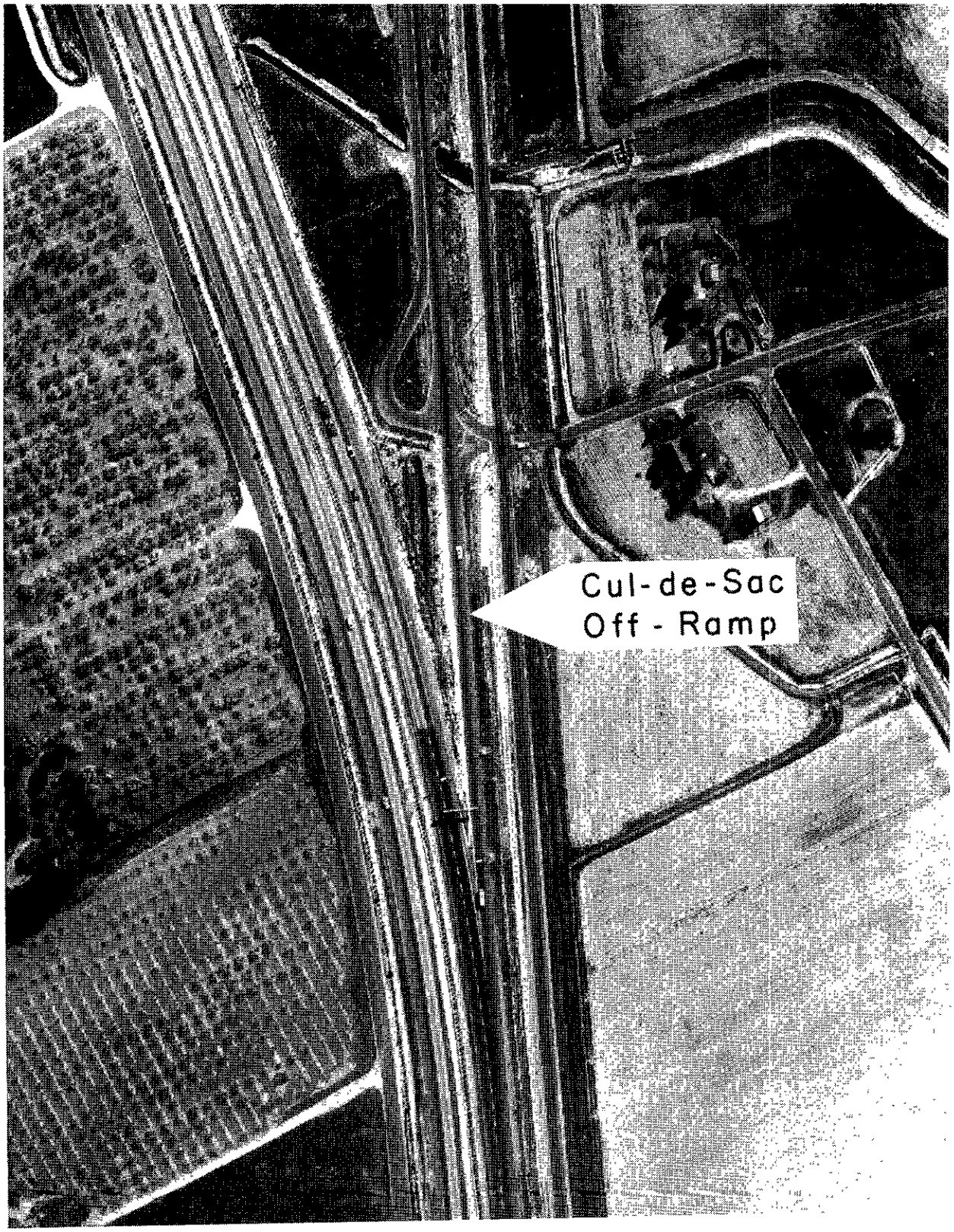
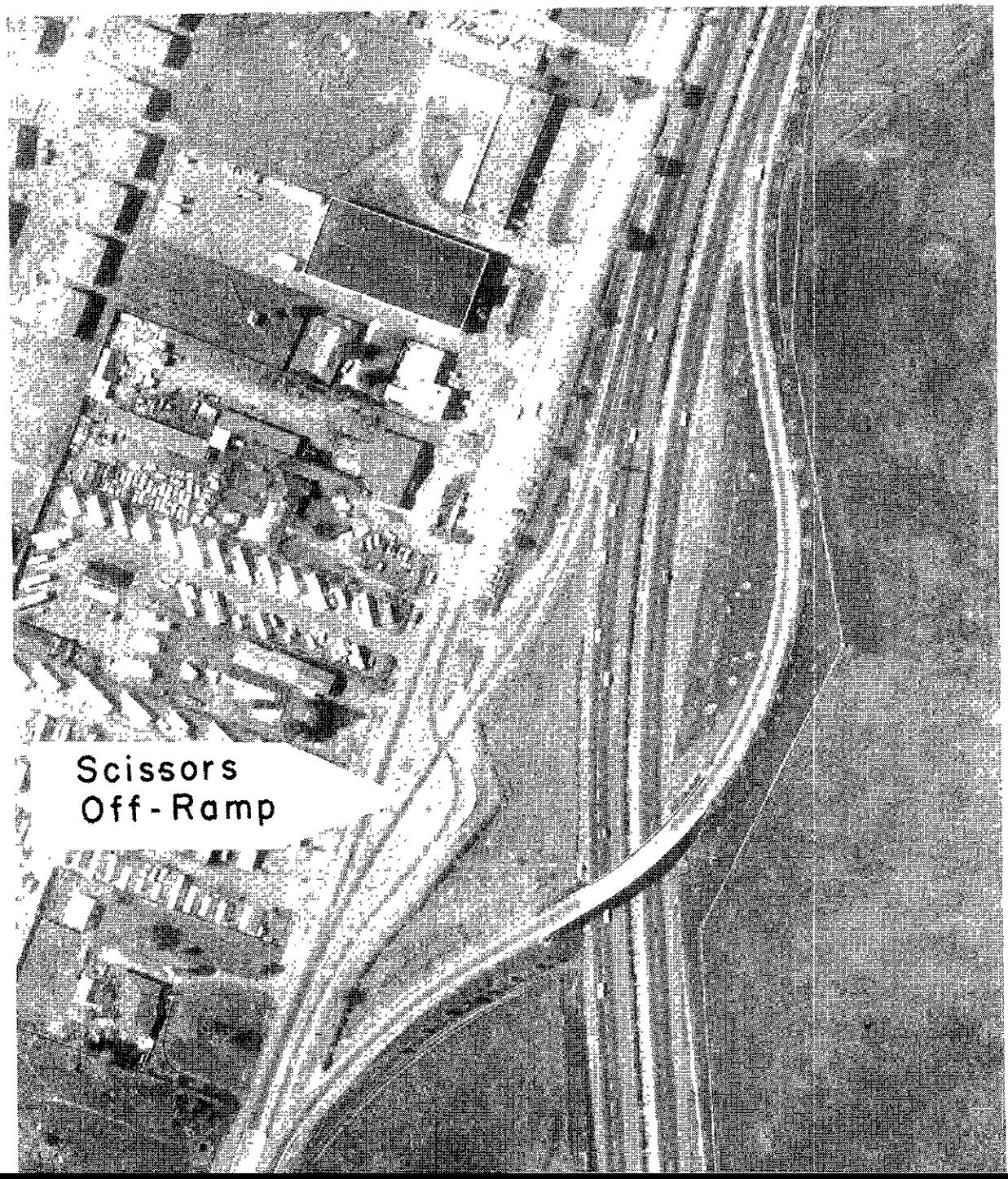
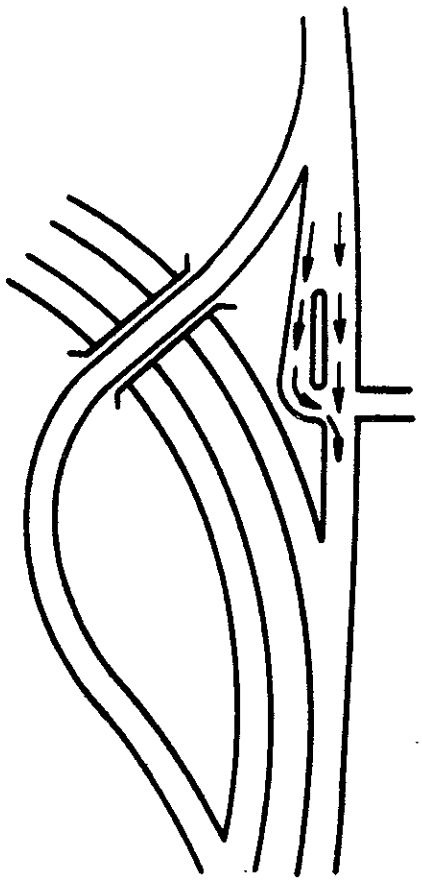
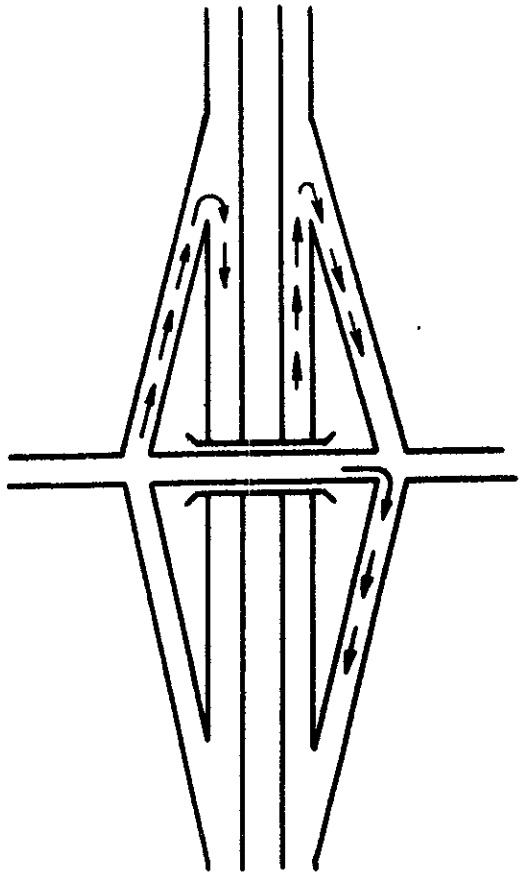


Figure 8



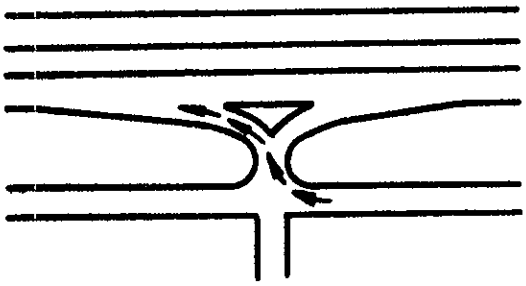


Cul-de-sac

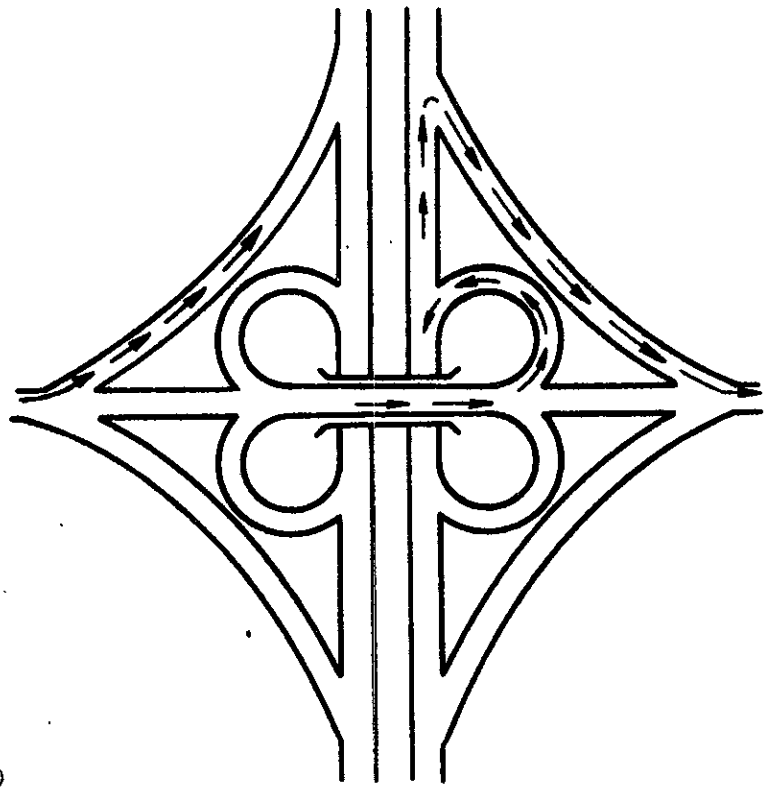


Diamond

Design of
Channelization Variable



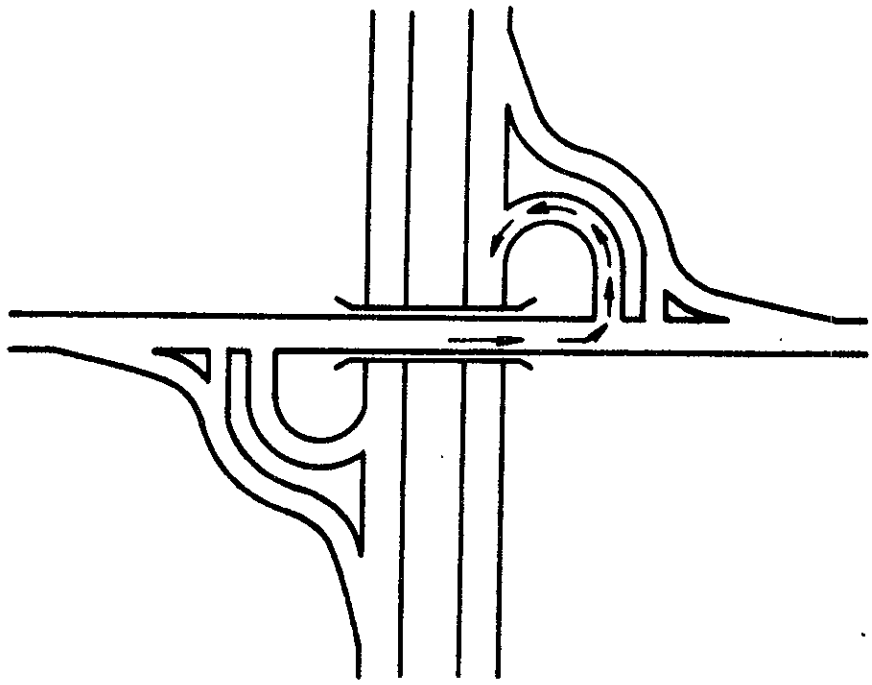
Buttonhook



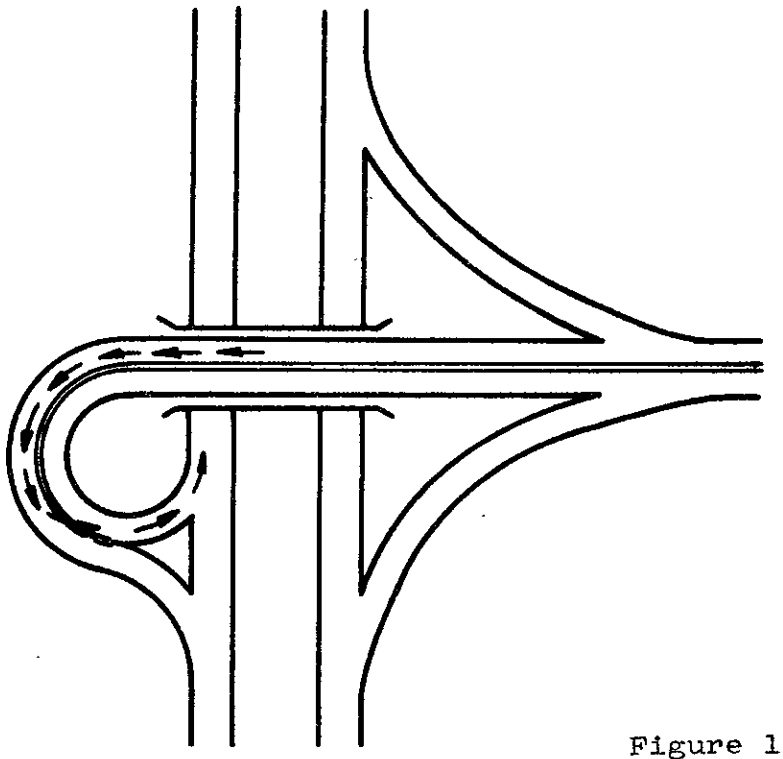
Cloverleaf

Figure 10

Typical Wrong-Way Movements at Various Types of Interchanges



Two Quadrant Cloverleaf



Trumpet

Figure 11

Typical Wrong-Way Movements at Various Types of Interchanges

TABLE VI

WRONG-WAY DRIVING ORIGINS BY RAMP TYPE & BY SOBRIETY

Ramp Type	Total All Studies		Drunk or H.B.D. Ability Impaired		All H.B.D.		Sober	
	No.	%	No.	%	No.	%	No.	%
** Diamond	167	37.5	33	39.3	66	40.7	101	35.7
Loop (Full Cloverleaf)	31	7.0	8	9.5	14	8.6	17	6.0
Loop (2 Quad. Cloverleaf)	32	7.2	5	6.0	11	6.8	21	7.4
Buttonhook	40	9.0	11	13.1	21	13.0	19	6.7
Trumpet	38	8.5	6	7.1	7	4.3	31	11.0
Cul-De-Sac or Scissors	41	9.2	7	8.3	15	9.3	26	9.2
Unclassified	96	21.6	14	16.7	28	17.3	68	24.0
Sub Total (Known Locations)	445	100%	84	100%	162	100%	283	100%
Unknown Locations	156	*(26.0%)	76	*(47.5%)	103	*(38.9%)	53	*(15.8%)
Total	601		160		265		336	

*Percent of incidents in sobriety class shown whose origin of wrong-way entry was unknown

**See page 27 for definition

volumes.

This study has reenforced previous conclusions that the ramp terminal design at the crossroad or local road be such as to make wrong-way entry to the ramp very difficult or require indirect and unnatural driving maneuvers.

F. Expressways

Expressways on the California Highway System are controlled access divided highways with public road intersections at grade and an occasional private driveway. Each year a few miles of this type facility are placed in operation. The total mileage of divided expressway is gradually being reduced as many miles each year are converted to freeways.

Wrong-way driving on 805 miles of expressways in 1963 caused 137 accidents compared to the 142 accidents on 1327 miles of freeways (See VI - Wrong-Way Driving Accidents). In the two nine-month incident studies, a total of 354 wrong-way incidents were detected (Table VII). None were detected in the reporting cities since all but 92 miles of the expressways are in rural areas. It was possible to determine the origin of the wrong-way driving in 304 of the 354 incidents. Notice that the number of incidents decreased from 187 in 1962 to 167 in 1964.

In both studies approximately one-half of the incidents originated at grade intersections with median openings. A few more originated at grade intersections without median openings, where only right turns are permitted. The number of incidents originating at intersections

TABLE VII

WRONG WAY DRIVING ORIGINS-EXPRESSWAYS

	CHP REPORTED 1964 Study		CITIES REPORTED 1964 Study		CHP REPORTED 1962 Study		TOTALS All Studies	
	No.	%	No.	%	No.	%	No.	%
Entered at an intersection (Median opening)	67	47.2	0		92	56.8	159	52.3
Turned wrong-way from undivided road transition or driveway (no median opening)	7	4.9	0		12	7.4	19	6.2
Drove across median divider	4	2.8	0		2	1.2	6	2.0
Drove thru median opening (not at intersection)	35	24.7	0		17	10.5	52	17.1
Made U-turn in traffic lanes	26	18.3	0		31	19.1	57	18.8
Other	3	2.1	0		8	5.0	11	3.6
	142	100%	0		162	100%	304	100%
Maneuver Unknown	25		0		25		50	
Total	167		0		187		354	

decreased by 25 (from 92 to 67). Most of the decrease (17 incidents) was during daylight hours. It is felt the pavement arrows painted at most of these intersections during the interim between the two studies caused this reduction.

Many different combinations of intersecting streets and parallel frontage roads are encountered at expressway intersections (Figure 12).

Besides the usual left-turn wrong-way moves, many drivers were obviously confused by the various combinations of two-way frontage roads and one-way 2-lane expressway lanes. Drivers desiring to turn right into a frontage road parallel to the main line instead turn right into the opposite direction lanes of the expressway. Some of the wrong-way moves originate at the expressway intersection median left turn pockets. Drivers intending to turn left and then right into an adjacent frontage road, instead turn right too soon into the opposite direction lanes on the expressway (Type A, Figure 12).

Previous to this study a single "ONE WAY ARROW" sign had been used in the median (Type A & B, Figure 12) for each direction of travel. The wrong-way drivers in each of the two above mentioned expressway maneuvers could see only the back of the sign pertaining to his wrong-way move. When the incidents containing these moves were first noticed during the study, the signing was investigated and additional one-way signs as shown in Figure 12, Type A and Type B were made a part of all expressway intersections

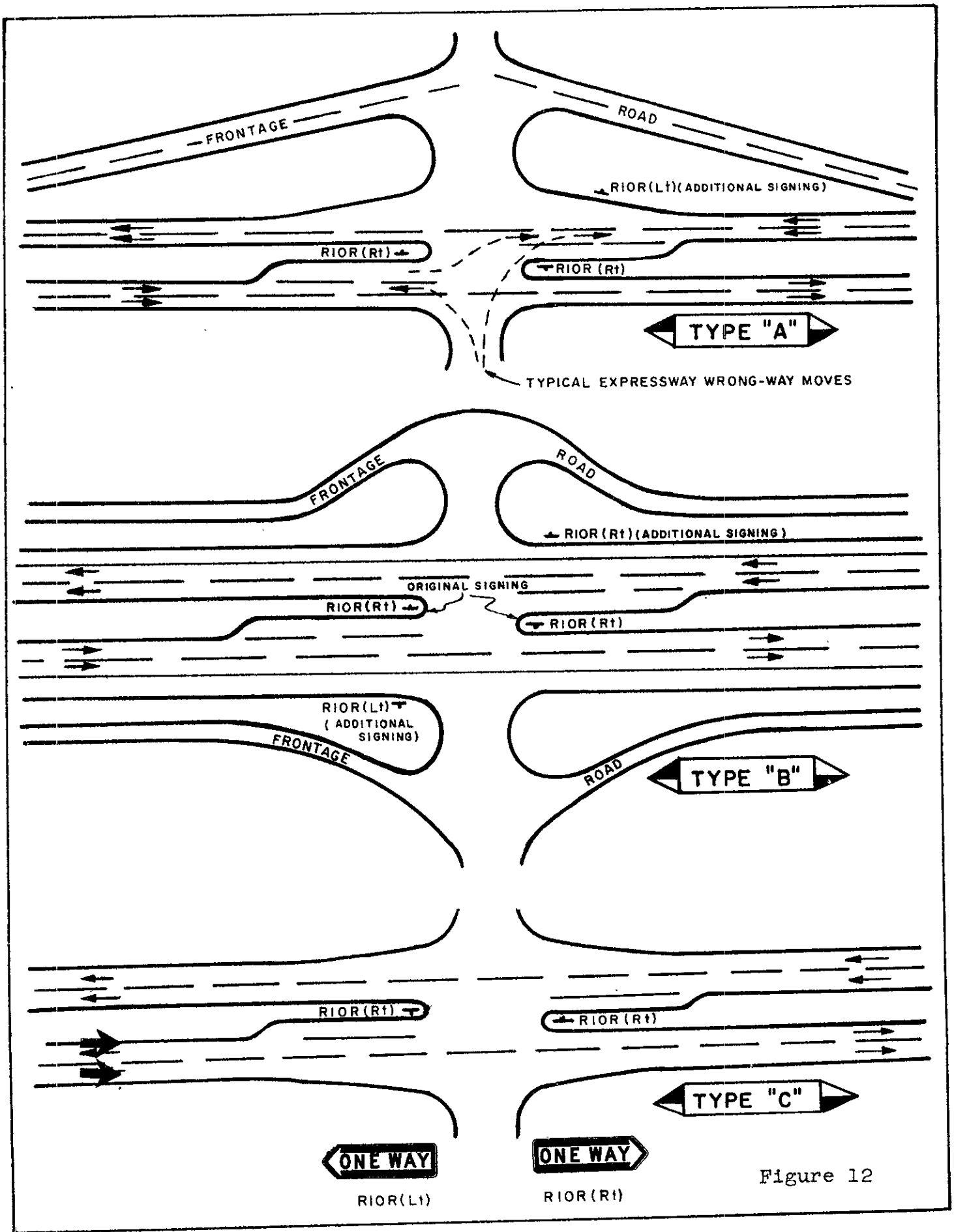


Figure 12

adjacent to frontage roads.

Signing at these locations is difficult. Although the direction of the arrow applies to the roadway in front of it, this may not always be obvious to drivers. Signing to the frontage road name also is difficult because of the multiple roadways.

The number of wrong-way incidents originating at non-intersection median openings doubled (from 17 to 35). Pavement arrows are not usually placed at these locations but the increase in incidents indicates that arrows may also be needed at these locations.

G. Time of Day in Wrong-Way Driving

Figure No. 13 shows the hour of day distribution of average hourly traffic volumes on divided highways, wrong-way incidents, and wrong-way accidents. Fifteen control stations used in obtaining the Annual Traffic Census were selected at random and the two way volumes at these locations were computed to arrive at the hourly traffic volume curve.

The morning peak volume of traffic occurs near 8 a.m. At noon, there is another peak and at approximately 5 p.m. the maximum hourly volume is reached. After 6 p.m. there is a steady decline until at 4 a.m. the smallest volume is recorded.

Wrong-way driving is lowest at about 6 a.m. The curve reaches a morning peak at about 11 a.m. At 2 and 3 p.m. in the afternoon the curve begins to rise slowly to its peak at about 2 a.m. The two peaks can be attributed

WRONG-WAY DRIVING ACCIDENTS & AVERAGE HOURLY VOLUMES ON DIVIDED HIGHWAYS

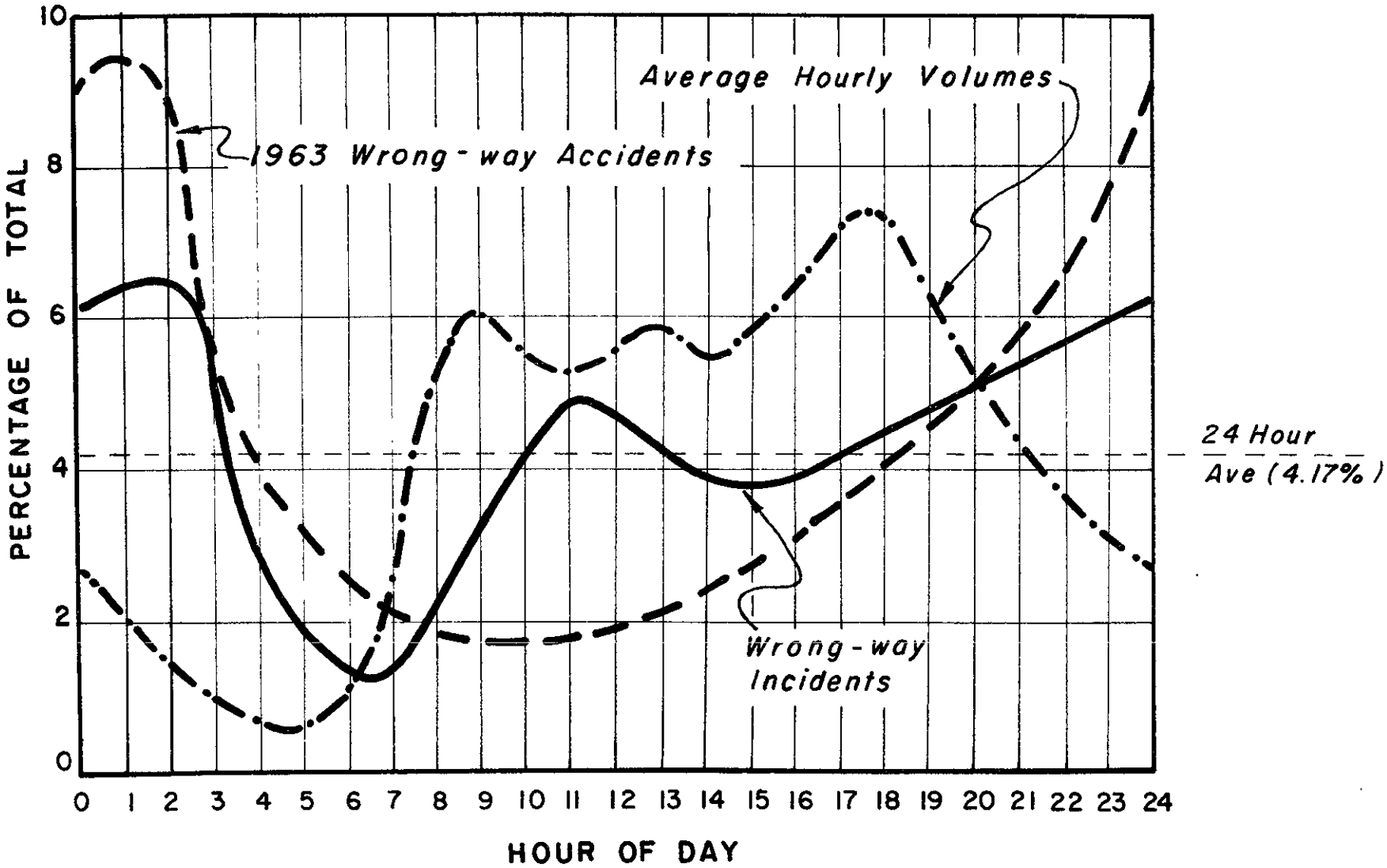


Figure 13

to two distinct causes. The 2 a.m. high coincides with the bar closing time in California. At this hour of the day over 6% of wrong-way incidents occur while only about 1% of the vehicle miles of travel occurs. This peak is caused by drivers under 59 years of age (See page 16) and is heavily influenced by the consumption of alcohol.

The 11 a.m. peak is caused by drivers over 60 years of age. If the incident curve did not include over 60 age drivers, the curve from 6 a.m. to the 2 p.m. peak would be practically a straight line.

Wrong-way driving accidents occur at a rate above the travel rate between 7 p.m. and 6 a.m. It rises gradually during the early evening hours as more and more of the drivers have been drinking and are fatigued and then drops very rapidly after 2 a.m. after the bars have closed and the drinking drivers begin to get off the road.

The next section of this report supplies further information on wrong-way accidents.

VI. WRONG-WAY DRIVING ACCIDENTS

A. Freeway and Expressway Accidents of 1963

A tabulation of freeway and expressway accidents caused by wrong-way drivers was secured from the 1963 California accident records (1963 data was the latest available in all severity classes). The totals by accident severity and the number of fatalities are shown below.

	Fatal	Injury	P.D.O.*	Total	Fatalities
Freeway	16	77	49	142	19
Expressway	14	64	59	137	20
Totals	30	141	108	279	39

In 1964, 53 persons were killed in 32 fatal wrong-way freeway accidents.

In 1963, 2.4 persons were killed per 100 freeway and expressway accidents; whereas, 14.0 persons were killed for each 100 wrong-way accidents. This means that wrong-way accidents are about 6 times more likely to produce a fatality than the average of all freeway and expressway accidents. In 1964, this ratio was probably higher.

Out of every 100 freeway or expressway accidents in 1963, 44.2 resulted in an injury or fatality. Out of 100 wrong-way accidents, 61.2 resulted in an injury or fatality.

As might be expected, wrong-way accidents are more severe than most other types.

Table VIII shows the number of accidents by severity and driver condition. In 15 of the 23 fatal accidents where the condition of the driver was noted, the driver had been drinking to the degree that his ability to drive was ob[illegible]ly

*P.D.O. = Property Damage Only.

TABLE VIII

CONDITION OF WRONG-WAY DRIVER - 1963 W.W. ACCIDENTS
(Freeways & Expressways)

	Fatal Accidents		Injury Accidents		Property Damage Only Accidents		Total W-W Accidents	
	No	%	No	%	No	%	No	%
Drunk or H.B.D. Ability Impaired	15	62.5	54	40.3	31	39.2	100	42.2
H.B.D. - Ability Not Impaired or Unknown	5	20.9	28	20.9	17	21.5	50	21.1
Other Defects (Fatigue - Eyesight Hearing, etc.)	2	8.3	12	9.0	1	1.3	15	6.3
No Defects	2	8.3	40	29.8	30	38.0	72	30.4
Total Known Conditions	24	100%	134	100%	79	100%	237	100%
Condition Not Stated	6		7		29		42	
TOTALS	30		141		108		279	

impaired. In fact, only two of the wrong-way drivers out of the 24 fatal accidents were described by the investigating officer as having no defects. Inspection of Table VIII shows that as the severity of the accidents increases, a greater proportion of the wrong-way drivers involved had been drinking or had some defect. Only 72 of the 237 (30.4%) wrong-way drivers where condition was described had no obvious defect.

Figure 13 includes a curve showing the distribution of 1963 wrong-way accidents by time of day. This curve indicates an even more pronounced departure from the average hourly volume curve than does the wrong-way incident curve.

Table IX shows the light condition at the time of wrong-way accidents. Darkness and hence reduced visibility is undoubtedly a contributing influence on wrong-way accidents. Two-thirds (66.6%) of the 279 accidents occurred in the dark. Of the total incidents occurring during both studies, 56.9% occurred in the dark. As severity increases, so does the percentage occurring at night. Refer to Table V "Light Condition for Entered Freeway via Off-Ramp" (page 24) to compare the effect of darkness between incidents and accidents.

B. Freeway Fatal Accidents

During the four-year period of 1961 through 1964, there were 83 fatal wrong-way accidents on freeways. (See table). One-hundred twenty-six persons were killed and an additional 150 persons were injured in these 83 accidents.

TABLE IX

LIGHT CONDITION - 1963 WRONG-WAY ACCIDENTS

(Freeways and Expressways)

	Fatal		Injury		P.D.O.		Total	
	No.	%	No.	%	No.	%	No.	%
Daylight	5	16.7	48	34.1	40	37.0	93	33.4
Dawn or Dusk	1	3.3	3	2.1	1	0.9	5	1.8
Dark - No Street Lights	17	56.6	68	48.2	50	46.3	135	48.3
Dark - Street Lights	7	23.4	22	15.6	17	15.7	46	16.5
Total "Dark"	(25)	(83.3)	(93)	(65.9)	(68)	(63.0)	(186)	(66.6)
Total	30	100%	141	100%	108	100%	279	100%

FREEWAY FATAL WRONG-WAY ACCIDENTS

Year	No. of Accidents	No. of Persons Killed	No. of Persons Injured
1961	13	19	17
1962	22	35	37
1963	16	19	34
1964	32	53	62
Total	83	126	150

Approximately four fifths(78.2%) of the wrong-way drivers in fatal accidents whose sobriety was known had been drinking. (See table below)

Sobriety	No. of W-W Drivers	Per Cent
Had Been Drinking	50	78.1
Sober	13	20.3
Diabetic	1	1.6
Known Condition	64	100%
Unknown Condition	19	
Total	83	

The eight-hour period between 8 p.m. and 4 a.m. accounted for 65 of the 83 (78.3%) fatal accidents. The number of fatal accidents by light conditions is shown below.

FREEWAY FATAL WRONG-WAY ACCIDENTS

Light Condition	No. of Accidents	Per Cent of Total
Daylight	13	15.7
Dawn or Dusk	0	0.0
Dark - No Street Lights	39	47.0
Dark - Street Lights	31	37.3
Total "Dark"	(70)	(84.3)
Total	83	100%

The lane in which the fatal accidents occurred is

shown in the table below. Three-quarters of the accidents occurred in the lane adjacent to the median. Possibly these drivers thought they were proceeding in the right direction on a two way road and were traveling on their right. In several cases, the right-way drivers turned left into the median as the wrong-way driver turned right into the median also (the wrong-way driver's right shoulder). At relative speeds between vehicles of up to 150 miles per hour (closure rate of 220 feet per second), very little time is available to the right-way driver to take evasive action once he perceives the approaching wrong-way vehicle.

FREEWAY FATAL WRONG-WAY ACCIDENTS

Year	Accident Location			
	Lane #1 (Median)	Lane #2	Lane #3	Total
1961	11	2	0	13
1962	12	9	1	22
1963	15	1	0	16
1964	- - - Not Available - - -			
Total	38	12	1	51
Per Cent of Total	74.5	23.5	2.0	100.-

VII. STATEWIDE SIGN CHANGES

Early in the course of this study it became evident that new and revised signing would be desirable at off-ramps, on-ramps, at expressway crossroad intersections, and at transitions from undivided highways or expressways to freeways. As a result of testing in the Driving Simulation Laboratory of the Institute of Transportation and Traffic Engineering at the University of California, Los Angeles during Phase I of the study, it had been concluded that red reflective signing was highly desirable as an attention getting device to insure that wrong-way drivers would see whatever message was to be displayed on the sign.

Since the specific message to be displayed was unknown, a preliminary small scale field test was made of three possible signs. Each sign tested was 5 feet by 3 feet with white letters on red reflective backgrounds. The messages were "WRONG WAY--GO BACK", "STOP--GO BACK", and "GO BACK--YOU ARE GOING--WRONG WAY". Each of the signs were also augmented with a 5-foot long white on red "DANGER" sign. The three signs were installed on an on-ramp in Sacramento and 18 unsuspecting subjects were asked to follow an itinerary which included the on-ramp. Only one sign was used and it was installed on the right. Four of the 18 test subjects did not see the signs. Five did not react after seeing the signs.

The other nine slowed down and stopped. The fact that the sign was on the right side and the subject looked to the left as they approached the freeway probably contributed to the large number who did not see or did not react.

From this limited testing and from comments by the 18 subjects it was concluded that the word "wrong-way" was the best understood phrase and that the sign reading "GO BACK--YOU ARE GOING--WRONG WAY" best indicated to the subjects what he was doing wrong and what he should do to correct his error.

The "GO BACK--YOU ARE GOING--WRONG WAY" sign located at a secondary position on the off-ramp and various primary signs were then tested in the Driving Simulation Laboratory at U.C.L.A. The results of these tests will be published by the University in a separate report.

In summary the University determined that:

1. The black on white "DO NOT ENTER", which was adopted by California as standard in 1961, with a white on red "WRONG-WAY" sign combination is as effective as all other signs tested and more effective than the old standard white on black "DO NOT ENTER".
2. The white pavement arrow placed at all off-ramps after the first study phase should

be redesigned to have a wider and longer head and a longer stem to appear as an arrow to a wrong-way driver.

The findings of the Driving Simulation Laboratory tests, and the incident and accident studies indicated that additional signing might be effective. It was decided to make the following changes:

1. At Off-Ramps - An attempt will be made to develop a red no-go pattern at off-ramps. The replacement of all white on black "DO NOT ENTER" signs by black on white "DO NOT ENTER" signs was accelerated. These signs are to be augmented with white on red "WRONG WAY" signs (Figure 14). A new pavement arrow as shown in Figure 16 is to be placed at all off-ramps.
2. At On-Ramps - To complement the red no-go color scheme of the off-ramps, a green-go scheme is to be provided at on-ramps with the installation of green "FREEWAY ENTRANCE" signs. See Figure 15.
3. At all transitions from undivided sections to freeway sections - The 24 inch by 30 inch "KEEP RIGHT" signs will be replaced with 48 inch by 72 inch signs where median widths permit. In advance of the "KEEP

Figure 14

Figure 15

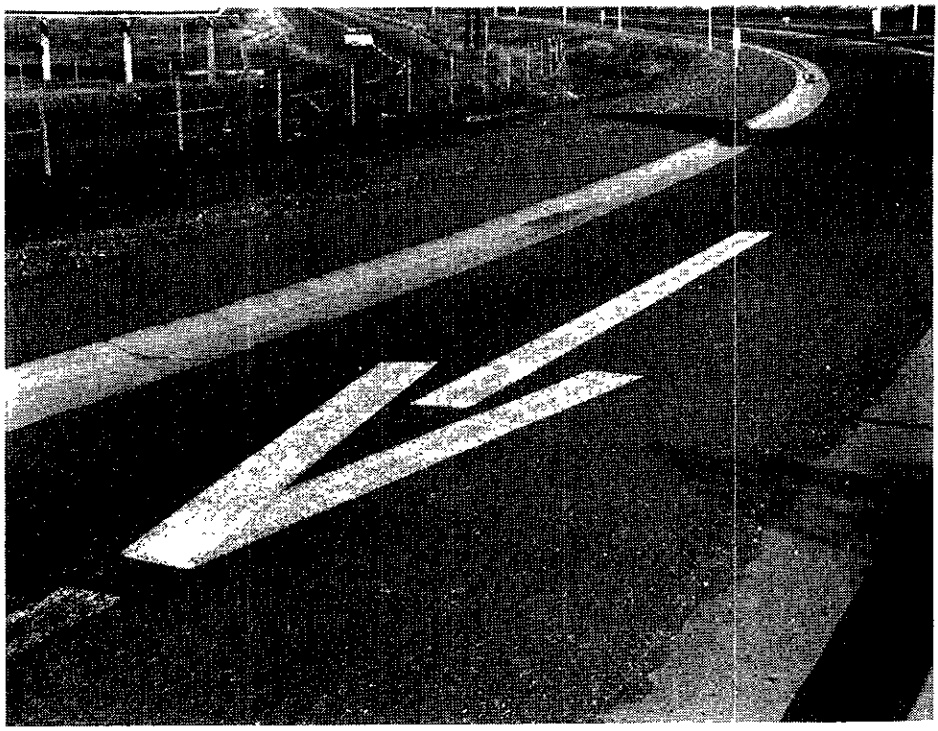


Figure 16

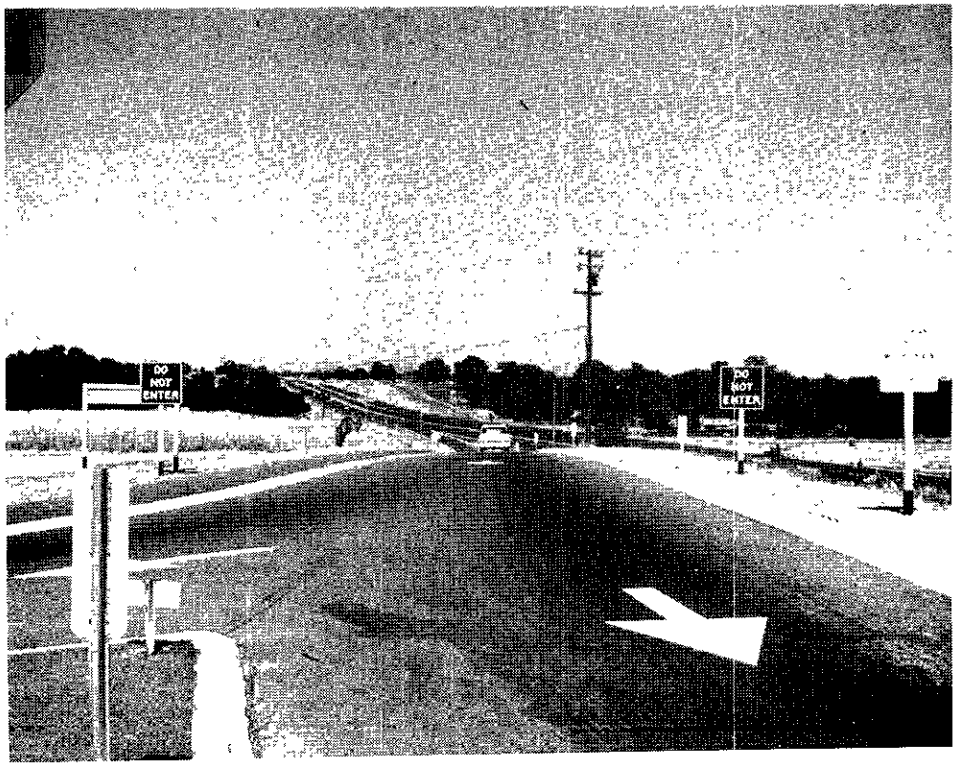


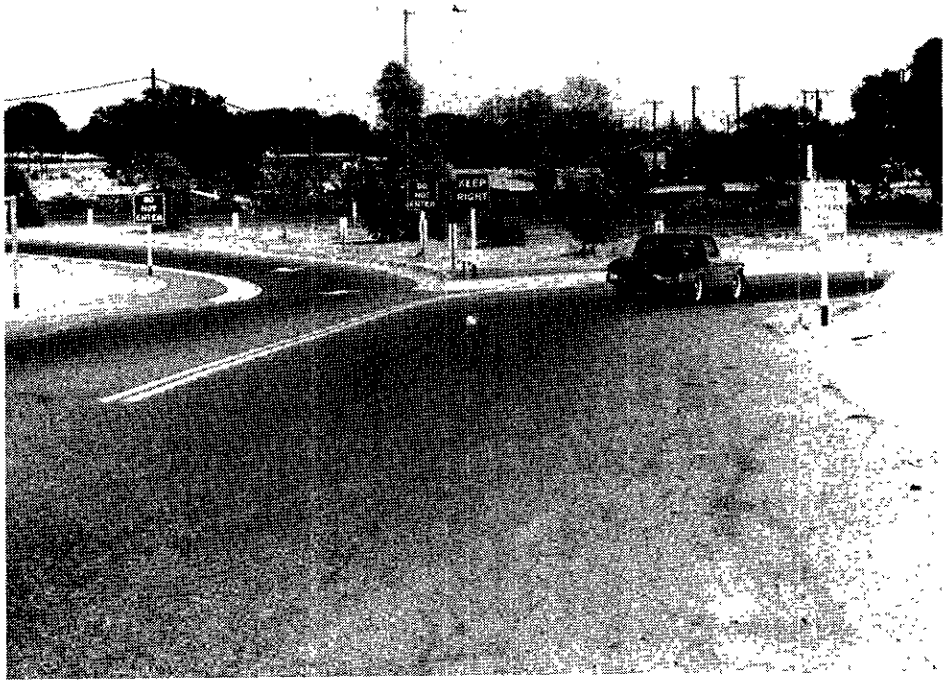
Figure 17

RIGHT" sign, a "DIVIDED ROAD" sign is to be installed. "DO NOT ENTER" signs are to be installed approximately 100 feet behind the "KEEP RIGHT" signs. These "DO NOT ENTER" signs will be special 12 inch black letters on white reflective background and will be supplemented by 72 inch by 28 inch red "WRONG WAY" signs.

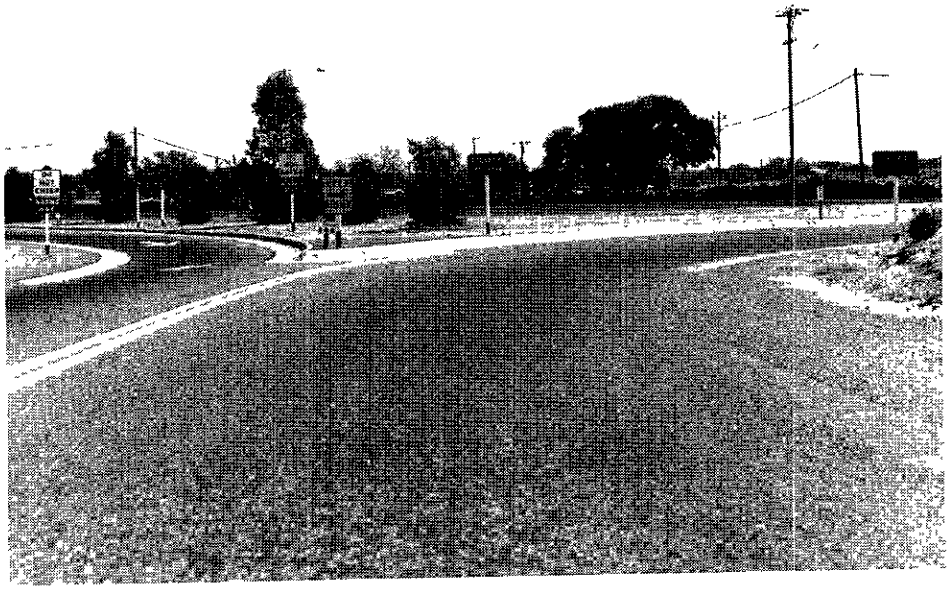
Pavement arrows as shown in Figure 16 will also be painted at 100 foot intervals in each lane in both directions of travel. (The old arrow designs are shown in Figure 17.)

4. At all transitions from freeways to expressways - The first median crossover or intersection at grade will be protected by special "DO NOT ENTER" signs. These signs will be oriented so as to be visible to the ~~right~~ WRONG-way driver only. Pavement arrows will also be installed at all expressway intersections at grade and at all median crossovers.

More detailed specifications and diagrams are included in Circular Letter 64-299 included in the appendix of this report. The old and the new signs are shown at a typical location in Figure 18.



Before

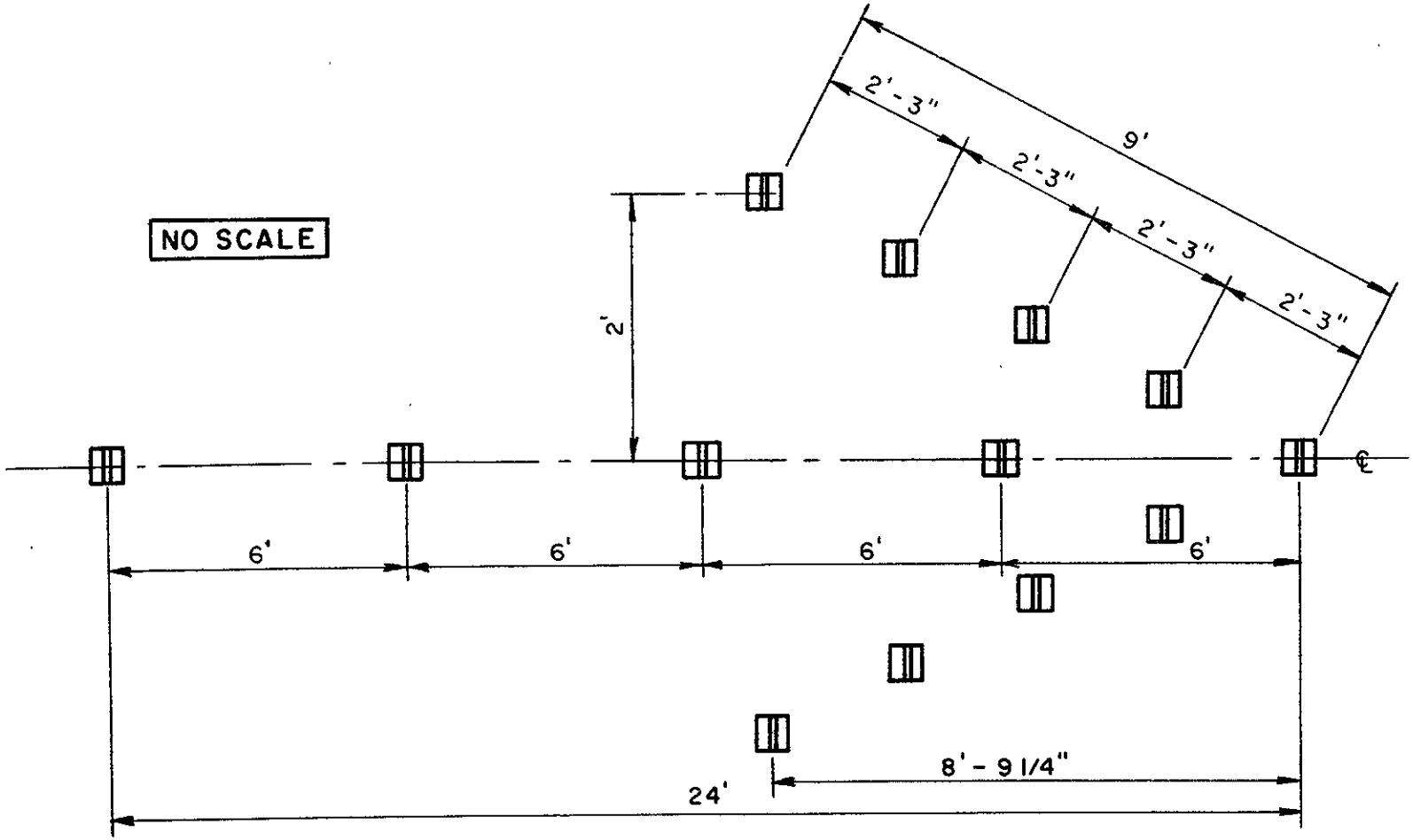


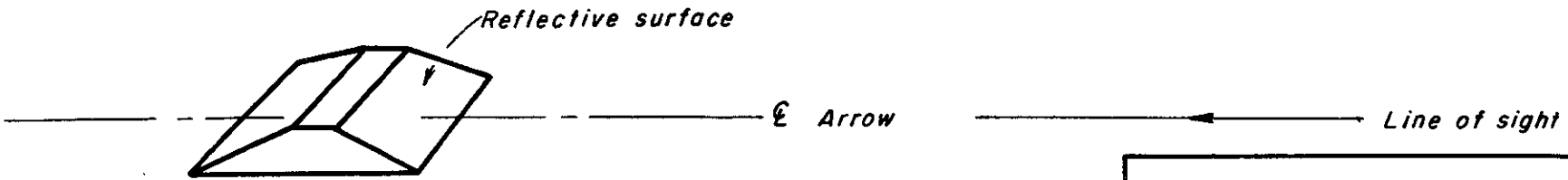
After

Figure 18.

The above sign and pavement markings changes are to be made during 1965. It is planned to conduct a third wrong-way incident study and a before and after accident analysis to determine the effectiveness of these signs.

In addition to the foregoing statewide measures, secondary white on red "GO BACK--YOU ARE GOING--WRONG WAY" signs will be installed at all off-ramps in the San Francisco Bay Area freeways. Special red retro-reflective pavement arrows as shown in Figure 19 will also be installed on these off-ramps and all off-ramps in the Los Angeles metropolitan area. The effectiveness of these devices will also be determined in the third incident study and before and after accident analysis.





NOTE:
All reflectors should be placed with reflective surface normal to ℄ & line of sight of the arrow

Detail of Red Reflector
PAVEMENT ARROW INSTALLATION

Figure 19

VIII. SPIKE BARRIER TESTS

The possibility of using spring loaded spike barriers (such as are installed at self-service parking lots and drive-in theatres) at off-ramps was investigated. These were tested to determine how effective they would be in disabling all types of wrong-way vehicles, whether they would cause any loss of control to both right-way and wrong-way vehicles, and whether they would stand up under heavy freeway traffic.

In a preliminary bending test, it was determined that the spikes would not withstand frequent repetition of heavy traffic. Full scale dynamic testing using a Volkswagon and a Dodge was conducted to determine the effectiveness of commercially available spikes (Figure 20) and modified spikes (Figure 21) in disabling vehicles and to determine whether loss of control was a problem. A separate report* has been published on this testing. Excerpts from the report follow:

1. The standard spike barrier will not effectively disable an automobile traveling against the spikes at speeds of from 15 to 60 mph for the following reasons:
   a. Spike penetration will puncture a tire but not cause a blow out. In 1 out of 7 runs against the spikes, the driver noticed an effect in air pressure in

*. "Full Scale Dynamic Tests on One-Way Spike Barriers" January 1965, Materials and Research Department, Division of Highways.

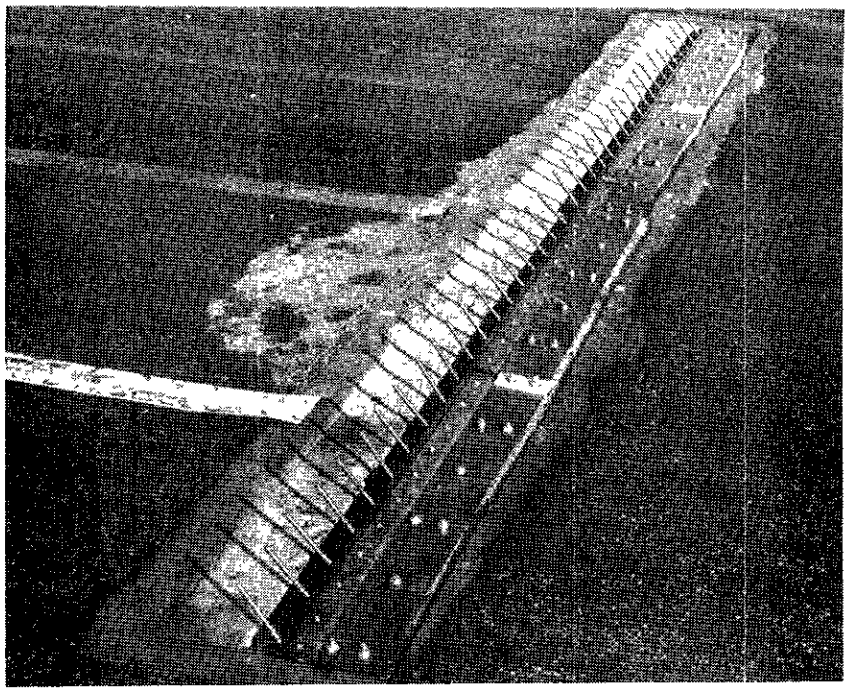


Figure 20

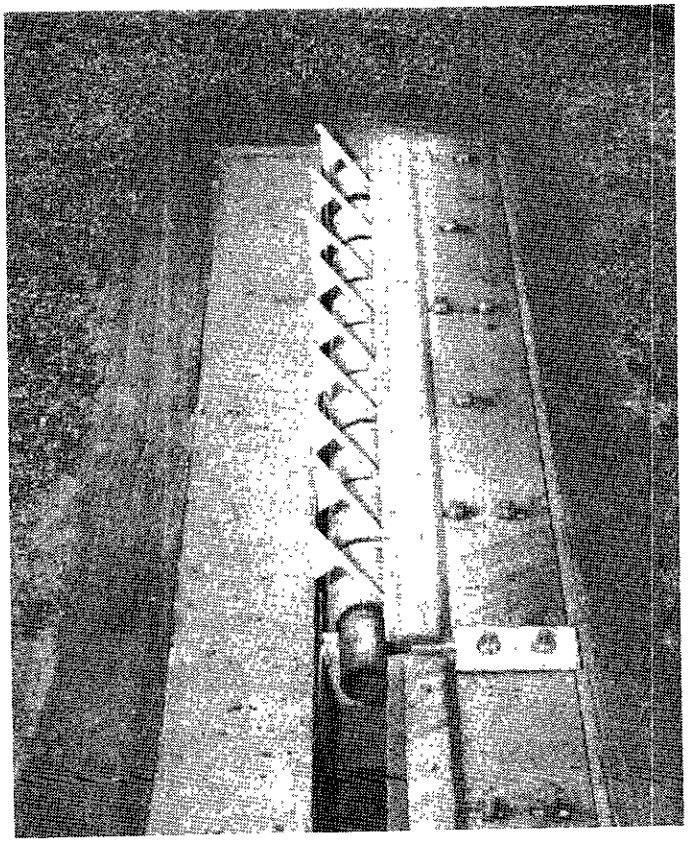


Figure 21

10 seconds, but in the other 6 runs no effect was noticed after 5 minutes.

b. The spikes are not close enough together to prevent narrow tires (5.60 and smaller), such as are used on compact and small foreign cars, from passing between them.

2. The addition of a "fish hook" barb to the spikes (Figure 21) enabled the spikes to rip a hole in the tire large enough to deflate the tire from 10 to 30 seconds after contact.

3. Addition of the barb, in one case, caused a permanent change in the angle of the spike such as to render it dangerous to right-way vehicles.

4. Blunt ended spikes allowed a tire to ride up over the spike without causing a puncture.

5. Test drivers indicated that it was impossible to determine the direction of the spikes when approaching them. Right-way drivers could be forced into a panic stop by this lack of assurance.

6. Although in these tests there was no loss of control or tendency of the test vehicles to roll, it cannot be assumed that this barrier would not create hazardous conditions for either an inexperienced driver, a vehicle with worn or tube type tires (not self-sealing), or a vehicle traveling at high speeds.

Figures 22, 23, 24 and 25 are photographs of run 15 of the series using a small foreign car equipped with new 4-ply tubeless tires and the spike barrier modified by addition of barbs. The first picture of the sequence shows the vehicle just passing over the barrier, the second is a frame from the high speed close-up motion pictures as the tire is being ripped, the third shows the vehicle with the right front tire just beginning to deflate, and the fourth a close-up of the damage done to the tire.

Figures 26, 27 and 28 are taken from the motion picture film of a wrong-way movement at the Stockton Boulevard off-ramp location of the automated sign described on page 69 . The first frame shows the wrong-way car about 100 feet past the detector loops. The second frame the driver is taking evasive action to the shoulder on his left about 175' past the detector. The third frame, about four seconds later, shows the semitrailer passing the 175' spot going the right way about 45 mph. If the wrong-way vehicle in this incident had been completely disabled by a spike barrier, a very serious accident would probably have resulted.

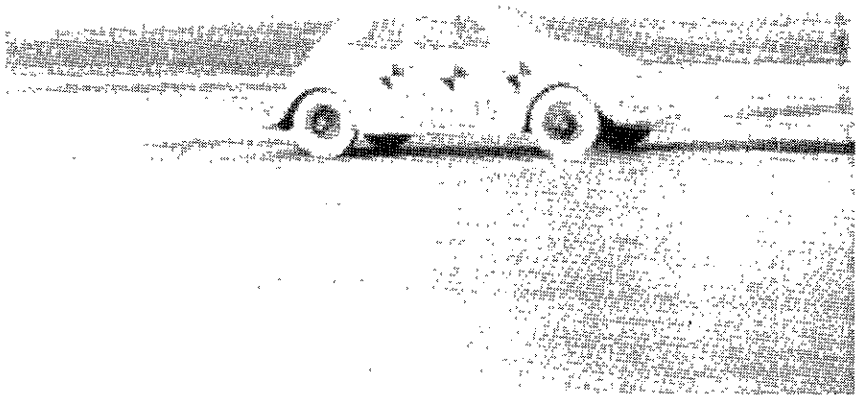


Figure 22

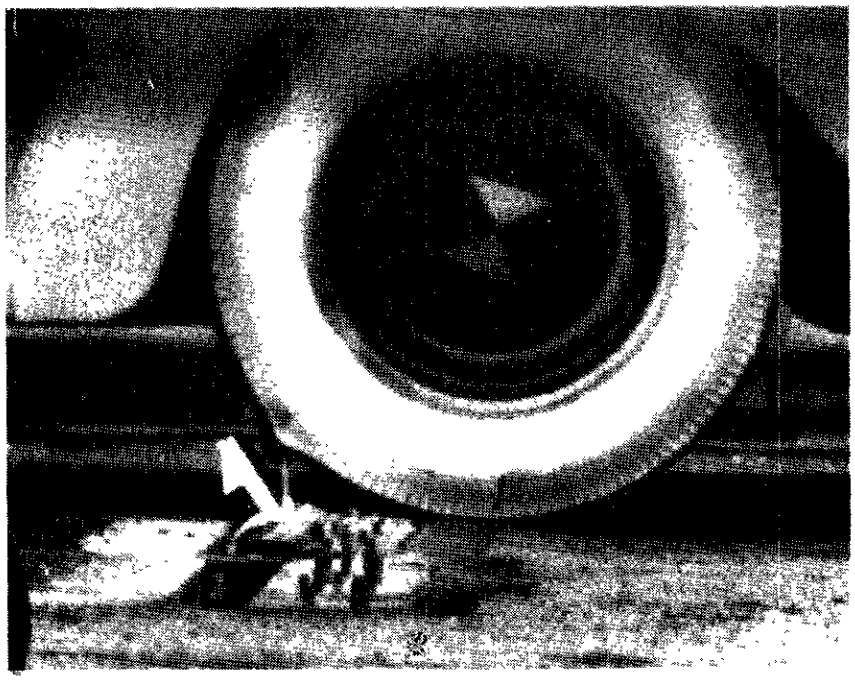


Figure 23

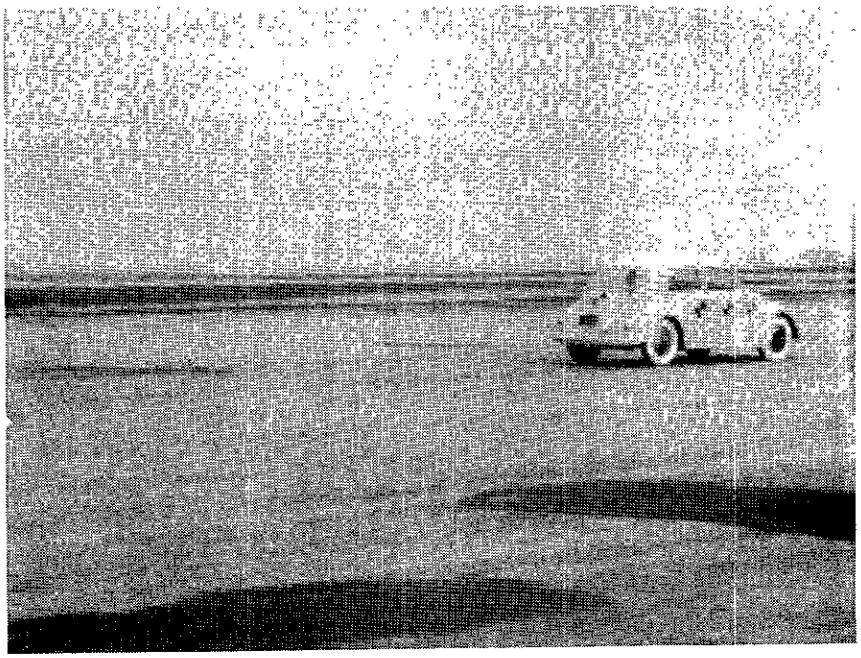


Figure 24

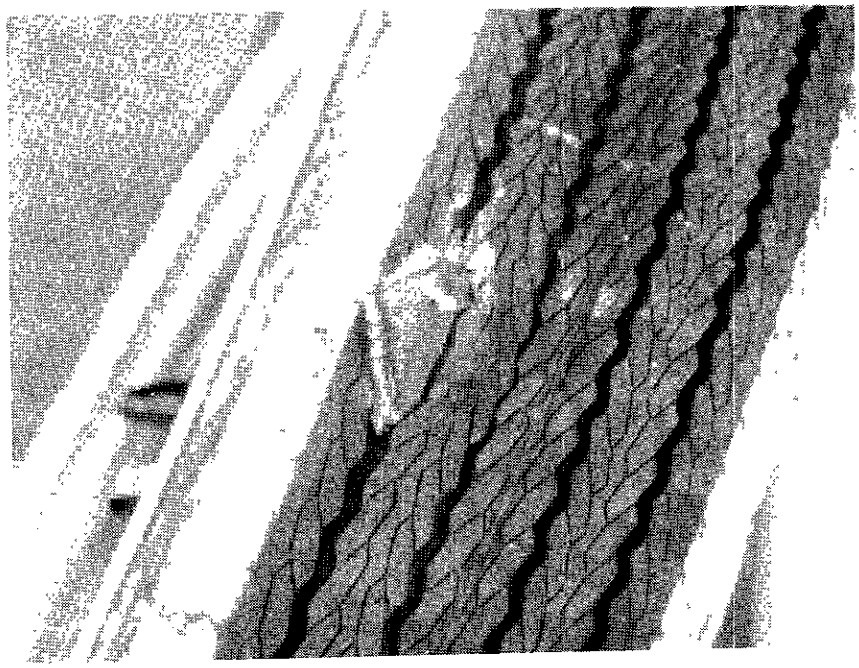


Figure 25

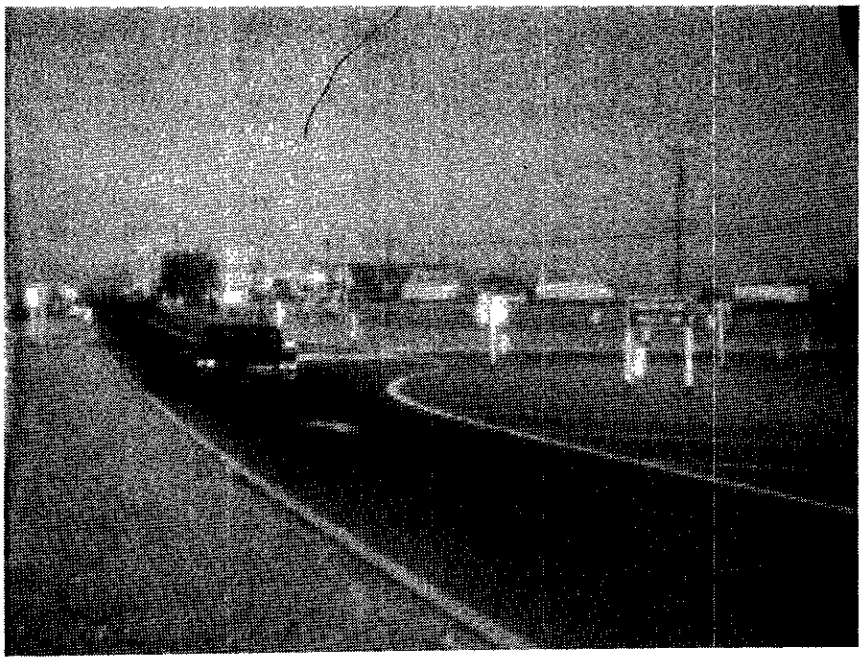


Figure 26

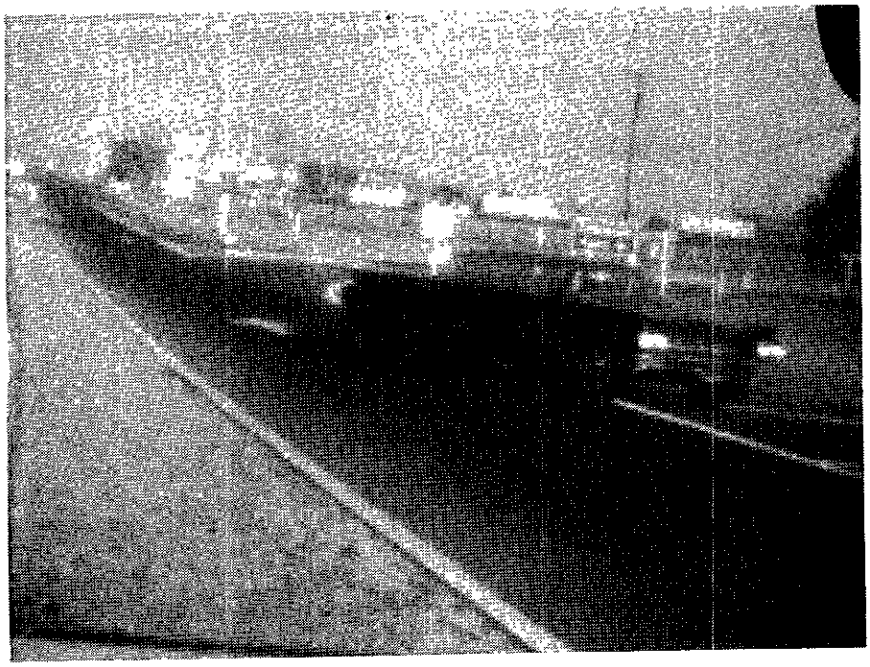


Figure 27

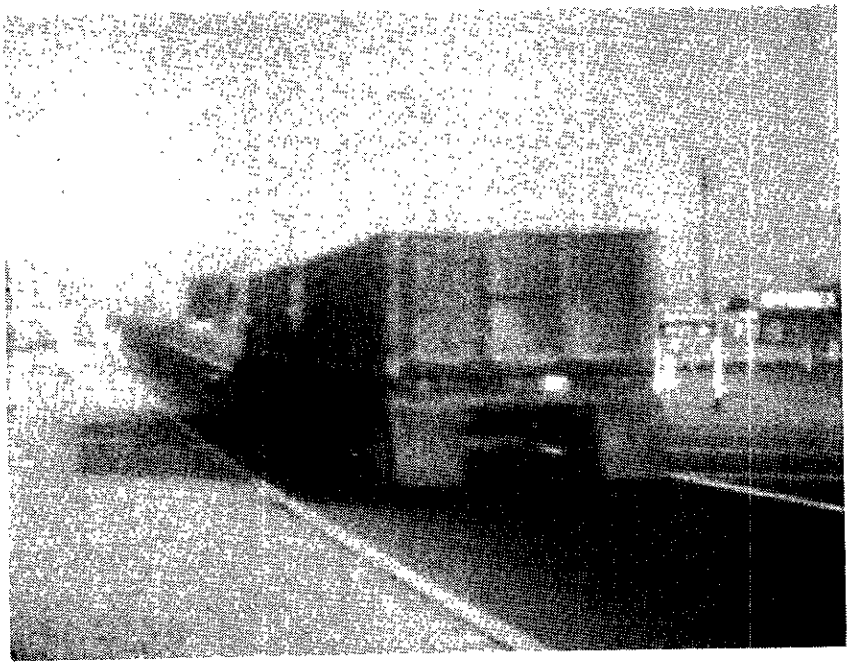


Figure 28

IX. WRONG-WAY DETECTOR AND AUTOMATIC SIGN DEVICE

For any barrier to be effective, the vehicle would have to be disabled. Many of the vehicles disabled by the barriers might in turn cause secondary accidents involving innocent vehicles. Because of this, an attempt was made to develop some device which would be effective in voluntarily preventing wrong-way driving. A device was developed which consisted of an illuminated and reflectorized white on red sign reading "GO BACK--YOU ARE GOING--WRONG WAY" supplemented with a 12 inch red traffic light and two horns, one with a steady sound and the other with a pulsating sound. In addition, the back of the sign was equipped with a flashing amber light to warn the right-way driver that an obstruction was on the ramp. The device (Figure 29) is activated by wrong-way vehicles only using directional inductance loop detectors.

The automatic sign was installed at the Stockton Boulevard northbound off-ramp approximately 5 miles south of Sacramento. The ramp had been the site of 9 wrong-way incidents in the first incident study. It carries approximately 2,000 vehicles per day, 15% of which are trucks. The freeway at this location carries approximately 20,000 vehicles per day.

As shown on the photograph, Figure 30, the ramp is located at the point where the new freeway alignment through the City of Sacramento leaves the old U.S. 99 route (Stockton Boulevard). The off-ramp allows northbound 99 users to follow a direct route into Stockton Boulevard.

Figure 29

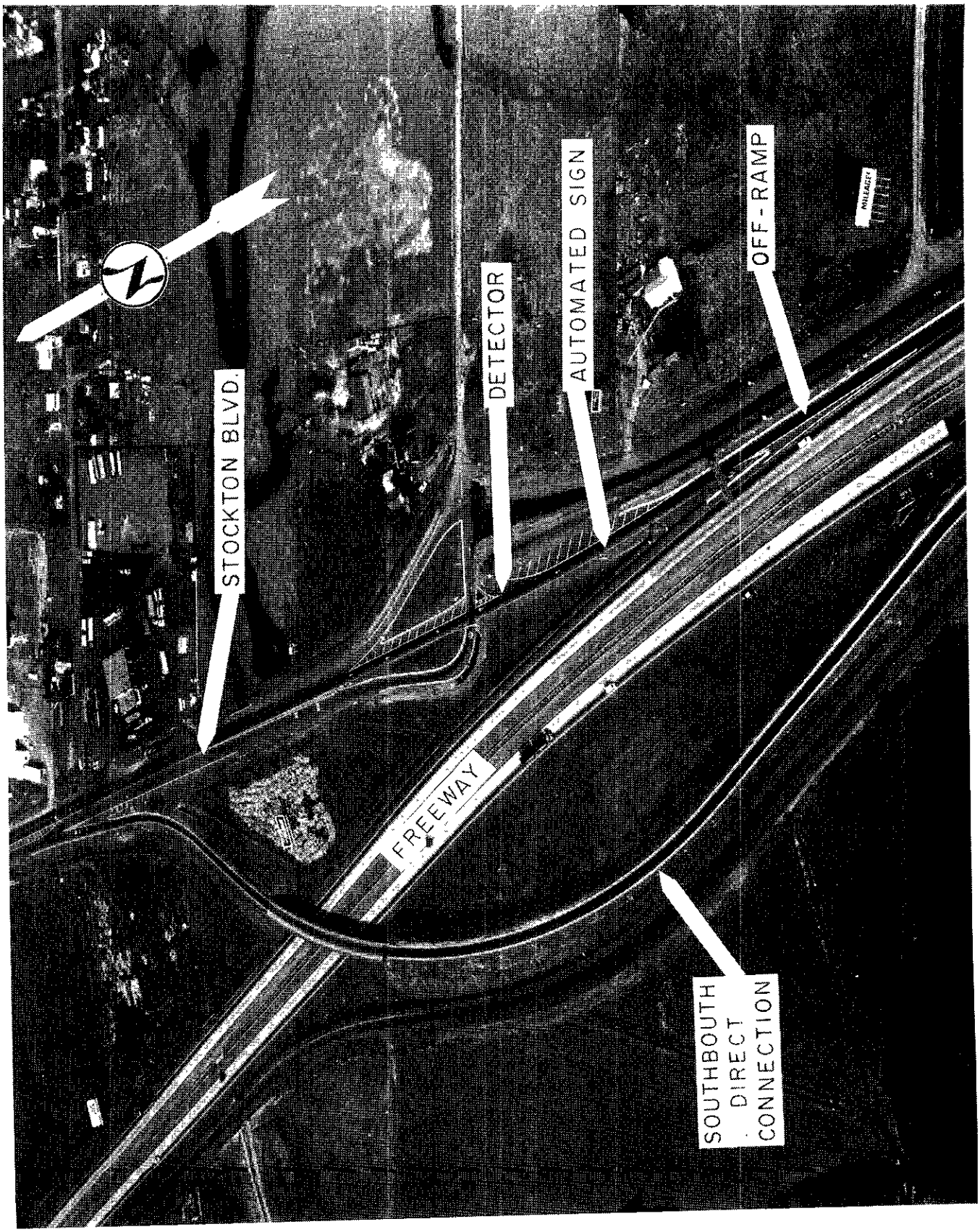


Figure 30

Southbound Stockton Boulevard users wishing to proceed south on the U.S. 99 freeway are supplied with a direct connection over the freeway that merges near the same point the northbound off-ramp diverges.

A movie camera was installed to record each wrong-way entry to determine the effectiveness of the device. At the writing of this report insufficient data has been obtained to make any definite conclusion. However, the following can be reported:

1. There are approximately 15 wrong-way entries to this ramp each month.
2. The wrong-way moves are almost equally divided between day and night.
3. Nine out of ten wrong-way drivers were observed to stop before they passed the automatic sign. (Other drivers that passed the sign may have stopped and backed up after the 15 second movie sequence ended.)

Testing of this device will be continued and results will be published in the report of Phase III.

X. CONCLUSIONS

Phase II of the wrong-way study has shown that the incidents of wrong-way driving have increased since 1962 in spite of some improvement in signing and the addition of white pavement arrows at all off-ramps. The study has shown, however, that the arrows have been effective in reducing the number of daylight wrong-way incidents originating at off-ramps and at expressway grade intersections. It is considered advisable to install these pavement arrows at all grade intersections of divided roads regardless of access control, at all median openings, and at transitions from undivided highways to divided highways. In addition, it would be desirable to paint one or two arrows in advance of all on-ramps which are in close proximity to off-ramps.

It is desirable, as far as reducing wrong-way entry is concerned, to design the crossroad terminal of the ramp so that wrong-way entry is either very difficult or so that it would require indirect or unnatural maneuvers.

Although some preliminary work has been done in these areas, more study is required to determine: (1) the ramp types and specific design details that are conducive to wrong-way entry, (2) devices which can effectively warn wrong-way drivers, (3) the effectiveness of new signs and revised signs now being installed at ramps, expressway intersections, and transitions to freeway sections.

State of California Department of Public Works **DIVISION OF HIGHWAYS** **CIRCULAR LETTER** **NO. 64-299**	File Classification: Planning Traffic - No. 87
TO: All District Engineers and Headquarters Office Department Heads	**Date Issued:** October 9, 1964 **Expires:** October 9, 1967
SUBJECT: Wrong-way Driving	
References: None	

In an attempt to reduce the occurrence of accidents caused by wrong-way driving on freeways, the following measures shall be put into effect as soon as possible:

1. Off-ramps

   a. Replace all white on black R11R's with the new standard black on white R11R's. Augment these R11R's with the "WRONG-WAY" sign, specifications for which are attached. The "WRONG-WAY" sign should be added below the R11R. Where new posts are used the "WRONG-WAY" should clear adjacent pavement or curb by 5 feet. W17R, W44R or other signs to warn or direct the right-way off-ramp driver should be placed on the same post and behind the R11R whenever possible. This placement will reassure the right-way driver he is driving in the correct direction and reduce the number of fixed objects.

   b. Replace, as repainting becomes necessary, all pavement arrows located 50 to 100 feet from the end of ramp with the pavement arrow shown in the attached specifications. The arrow near the end of the off-ramp is to remain the present design.

2. On-ramps

   Install green "FREEWAY ENTRANCE" signs as described in the attached specifications at all on-ramps. The attached diagram illustrates that these signs will be located in approximately the same position on the on-ramps with respect to the crossroad intersection as the R11R's are located on the off-ramps. The bottom of the "FREEWAY ENTRANCE" should clear adjacent

pavement or curb by 5 feet except at pedestrian conflict locations.

3. Improvements to be incorporated at the location of transitions from undivided sections to freeway sections are as follows:

   a. Replace 24" x 30" R7R "KEEP RIGHT" signs with the 48" x 72" size where median width permits. Location is as in Figure 8-601.3B of the Planning Manual. However, where width permits, the sign should be moved forward into the raised bar area.

   b. In addition, at an appropriate distance in advance of the "KEEP RIGHT" sign, a 48" x 48" W25R "DIVIDED ROAD" sign should be installed in a similar location as shown in figure 8-601.3B of the Planning Manual.

   c. "DO NOT ENTER" signs will be installed approximately 100 feet behind the "KEEP RIGHT" signs. These "DO NOT ENTER" signs will be the special 12" black letters on white reflective background and shall be designed as shown on the attached specification sheet. Add 72" x 22" red "WRONG WAY" signs below these special R11R's.

   d. Pavement arrows as shown in the attached specification shall be painted at 100 foot intervals on the traveled way, in both directions of travel, a distance of 150 feet each side of the "Control Point" in Figure 7-207.2 of the Planning Manual. An attached diagram illustrates this pavement arrow placement.

4. At transitions from freeway to expressway, the following measures will be taken:

   a. The first median crossover or intersection at grade shall be protected by the special "DO NOT ENTER" signs as specified above in Paragraph 3-c. These R11R's should be oriented (or louvered if necessary) so as not to be visible to right-way drivers.

   b. In addition, at all expressway intersections at grade and at all median crossovers, pavement arrows of the new design shall be placed where no arrows exist or where existing arrows need replacement.

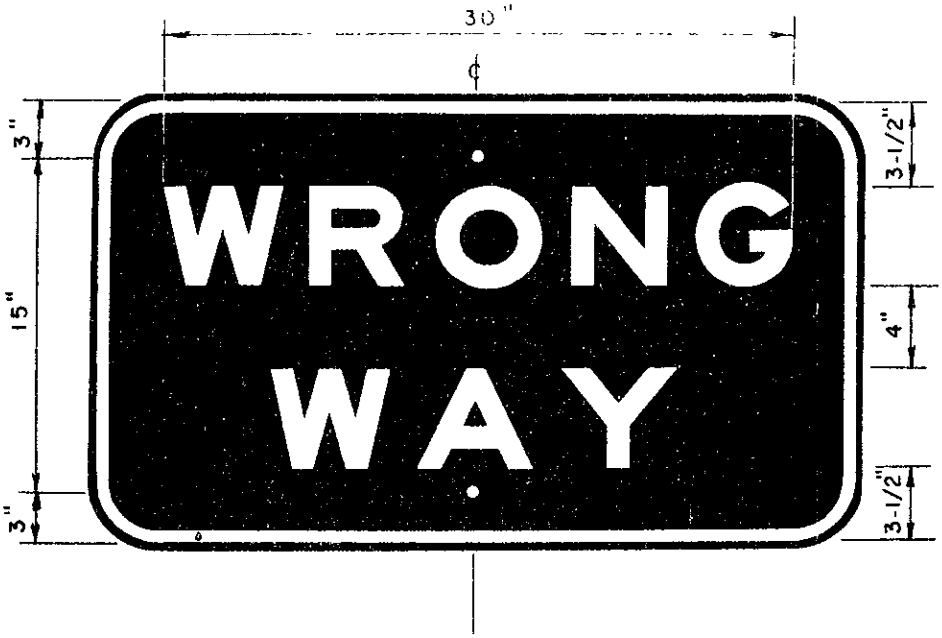
   Any of the above transitions, median crossovers or intersections at grade that are considered problem

locations should be augmented with reflectorized wedges, illumination, painted stripes or low profile bars.

Sign requisitions together with estimate of cost to complete the sign program and your recommendations as to performance by contract or day labor should be forwarded to Headquarters Traffic Department.

J. C. WOMACK
State Highway Engineer

Attachments



CODE NO.	SIZE	BORDER WIDTH	MARGIN WIDTH	LETTER SIZE & SERIES					SYMBOL		HOLE CENTERS	HOLE DIA.	CORNER RADIUS	REFLECTORS	
				LINE 1	LINE 2	LINE 3	LINE 4	LINE 5	STROKE	WIDTH				NO	SIZE
R65R-1	36"X21"	1/2"	3/8"	5"-F	5"-F						3" 15"	3/8"	3"		
											3"				

RED BACKGROUND WITH WHITE BORDER AND SYMBOL

REMARKS

CONDENSED SPACING USED ON LINE ONE SUBTRACT APPROX. 0.71" FROM EACH STD. "F" SPACING.

STROKE WIDTH: 0.22" PER INCH OF LTR HT

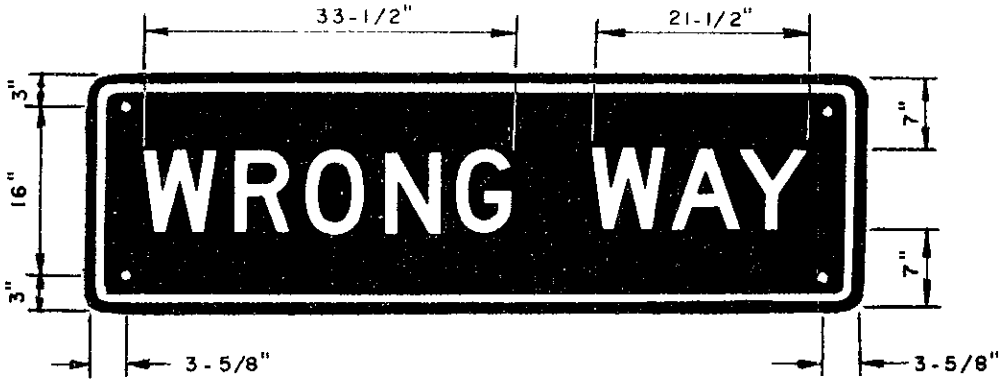
USE REFLECTIVE SHEETING ON BACKGROUND, MESSAGE AND BORDER.

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

APPROVED A. Rubin
TRAFFIC ENGINEER

11-9-64
DATE

REVISION



CODE NO.	SIZE	BORDER WIDTH	MARGIN WIDTH	LETTER SIZE & SERIES LINE 1	LINE 2	LINE 3	LINE 4	LINE 5	HOLE CENTERS	HOLE DIA.	CORNER RADIUS	REFLECTORS NO.	REFLECTORS SIZE
R65R-2	72"X22"	3/4"	1/2"	8"-D					3" 16"	3/8"	1-1/2"		
									3"				

RED BACKGROUND WITH WHITE BORDER AND SYMBOL.

REMARKS

CONDENSED SPACING USED: SUBTRACT APPROX. 1.13" FROM EACH STD. "D" SPACING.

STROKE WIDTH: 0.18" PER INCH OF LETTER HEIGHT

USE REFLECTIVE SHEETING ON BACKGROUND, MESSAGE AND BORDER.

POST HOLES THROUGH CHANNEL

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

APPROVED: R E Wilson
TRAFFIC ENGINEER

DATE 11-9-64 REVISION

CODE NO.	SIZE	BORDER WIDTH	MARGIN WIDTH	LETTER SIZE & SERIES LINE 1	LINE 2	LINE 3	LINE 4	LINE 5	HOLE CENTERS	HOLE DIA.	CORNER RADIUS	REFLECTORS NO.	REFLECTORS SIZE
G92R-1	36"X21"	1/2"		4"-D	4"-D				1-1/2" 18"	3/8"	3"		

GREEN BACKGROUND WITH WHITE BORDER AND SYMBOL

REMARKS

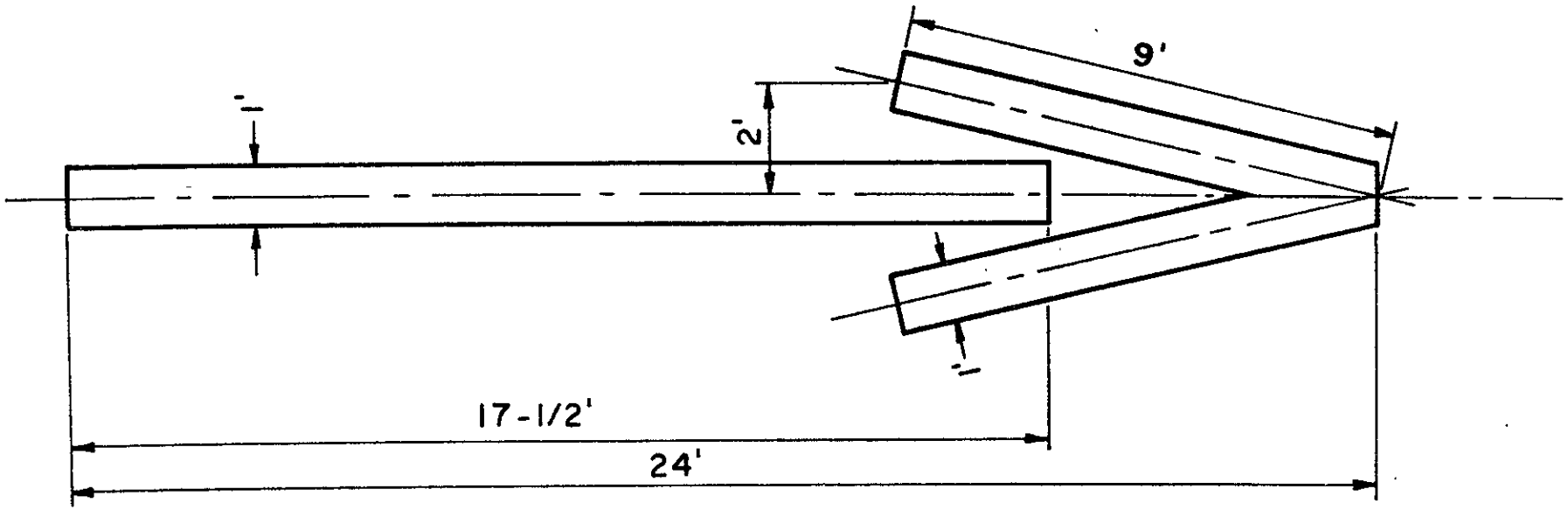
USE REFLECTIVE BACKGROUND, MESSAGE, AND BORDER.
STROKE WIDTH 0.18" PER INCH OF LETTER HEIGHT

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

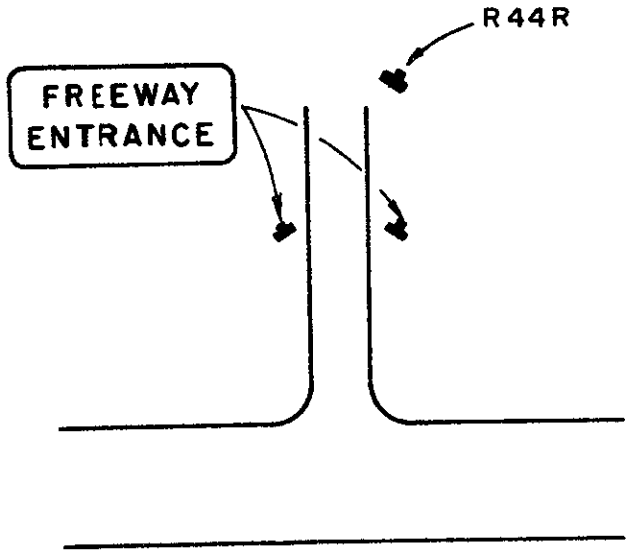
APPROVED: [signature]
TRAFFIC ENGINEER

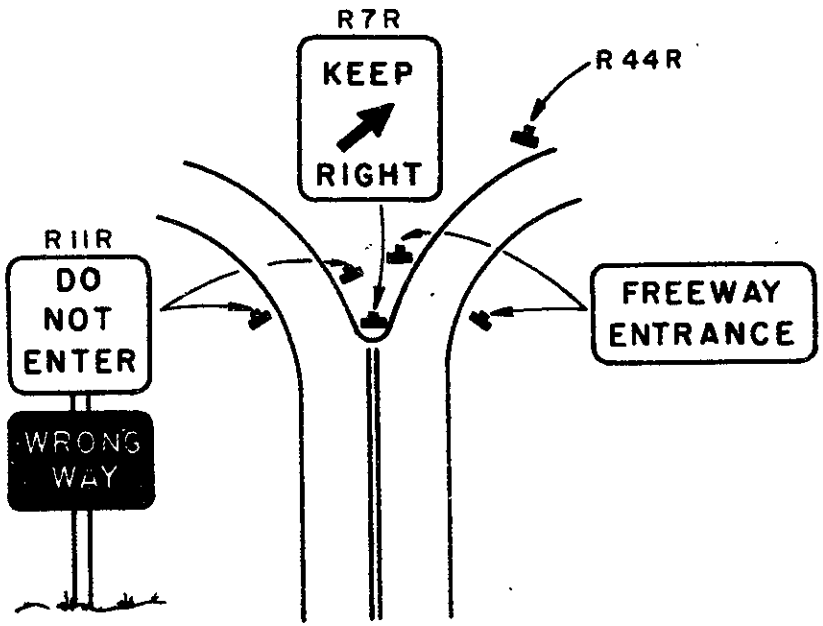
11-9-64
DATE

REVISION

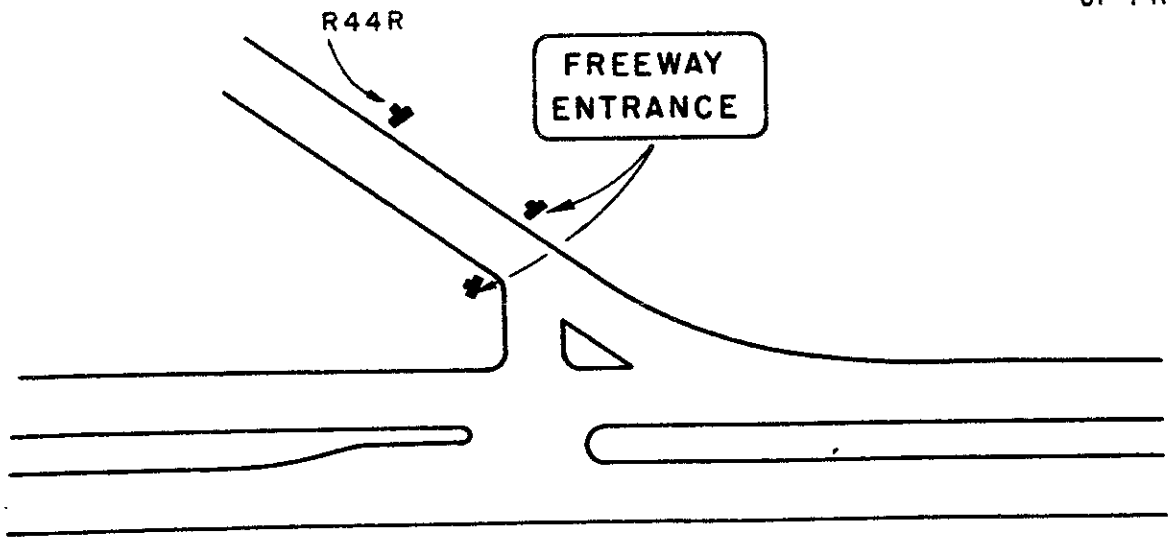


Detail of Painted
PAVEMENT ARROW



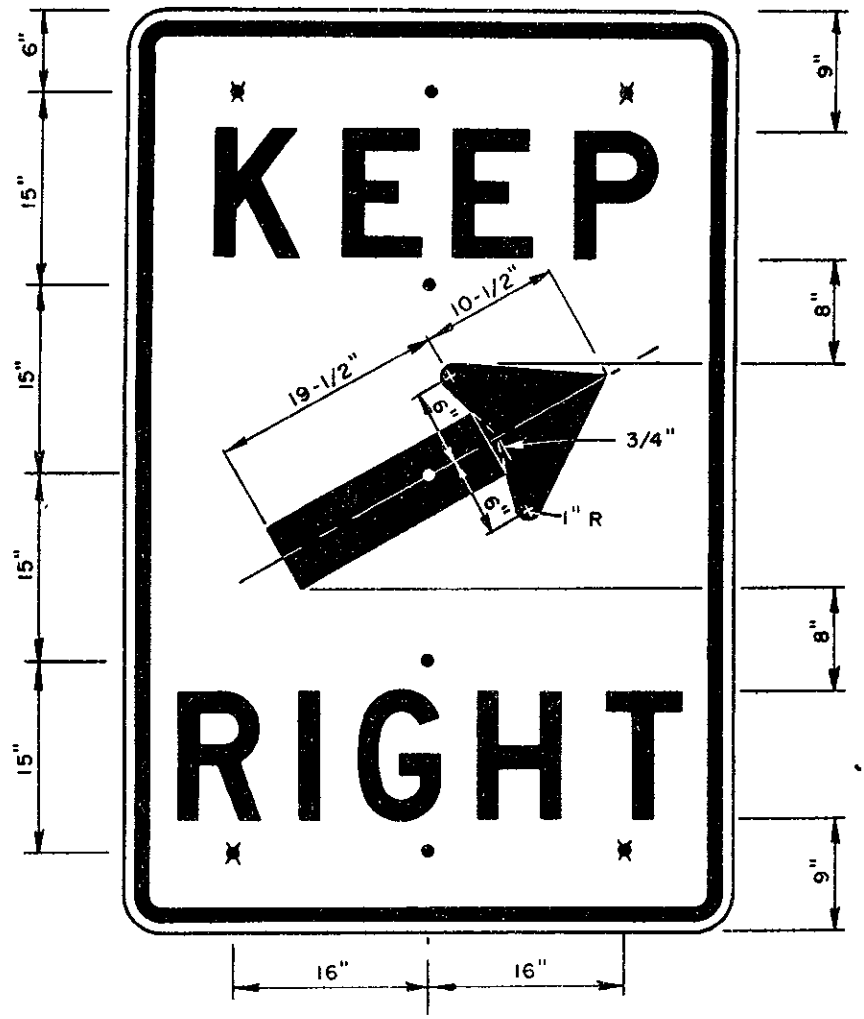


NOTE:
If necessary move R44R back of FREEWAY ENTRANCE sign.



On - Ramp Placement
FREEWAY
ENTRANCE SIGNS

R7AR - 5



CODE NO.	SIZE	BORDER WIDTH	MARGIN WIDTH	LETTER SIZE & SERIES LINE 1	LINE 2	LINE 3	LINE 4	LINE 5	ARROW HEAD	ARROW SHAFT WIDTH	HOLE CENTERS	HOLE DIA.	CORNER RADIUS	REFLECTORS NO	REFLECTORS SIZE
R7AR-5	48"x72"	1-1/4"	3/4"	10"-D	10"-D				11-1/2" X 14"	5-1/4"	6" 4@15"	3/8" ● 5/16" ■	3"		

WHITE BACKGROUND WITH BLACK BORDER AND SYMBOL

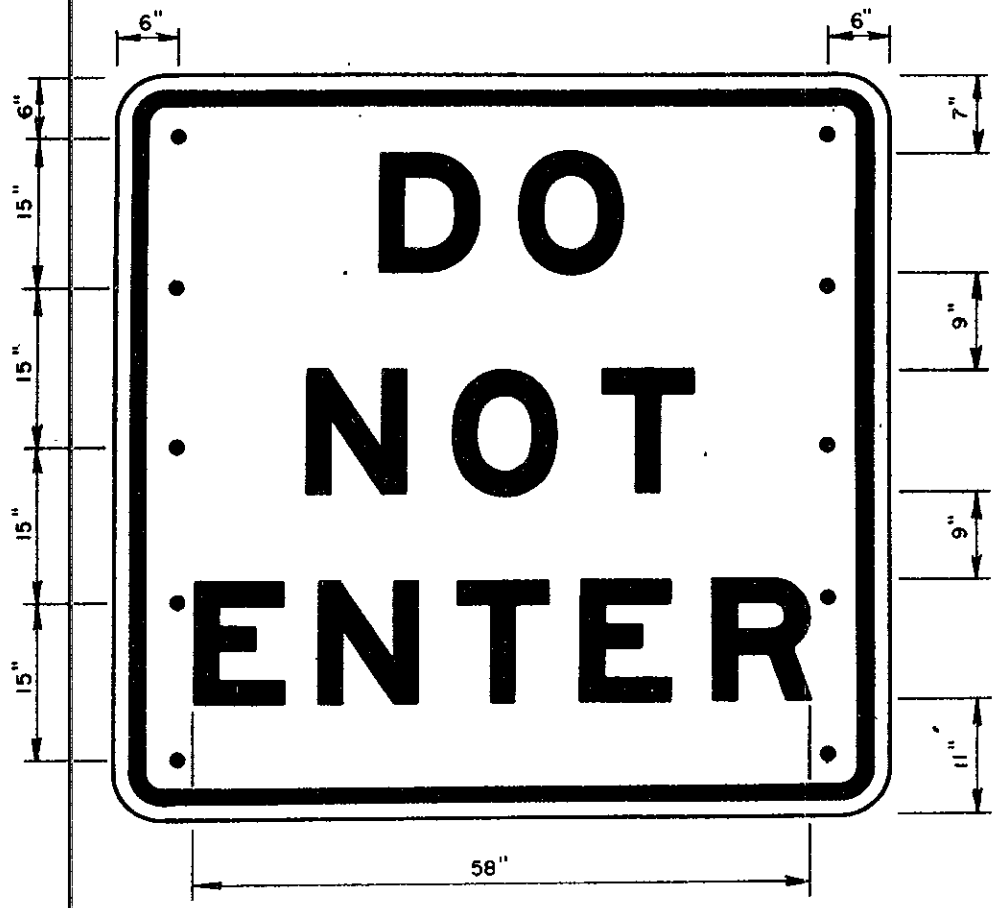
REMARKS

USE REFLECTIVE BACKGROUND
STROKE WIDTH 0.18" PER INCH OF LETTER HEIGHT
USE STANDARD "C" SPACING

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

APPROVED
TRAFFIC ENGINEER
8-14-64
DATE
REVISION

R11R
(Special)



CODE NO.	SIZE	BORDER WIDTH	MARGIN WIDTH	LETTER SIZE & SERIES					HOLE CENTERS	HOLE DIA.	CORNER RADIUS	REFLECTORS	
				LINE 1	LINE 2	LINE 3	LINE 4	LINE 5				NO.	SIZE
R11R (Special)	72"x72"	1-3/4"	1"	12"-E	12"-E	12"-E			6" 4@15"	3/8"	4-1/2"		

WHITE BACKGROUND WITH BLACK BORDER AND SYMBOL.

REMARKS

USE REFLECTIVE BACKGROUND
STROKE WIDTH: 0.20" PER INCH OF LETTER HEIGHT
CONDENSED SPACING USED - LINE 3:
SUBTRACT APPROX. 1.43" FROM EACH STANDARD "E" SPACING

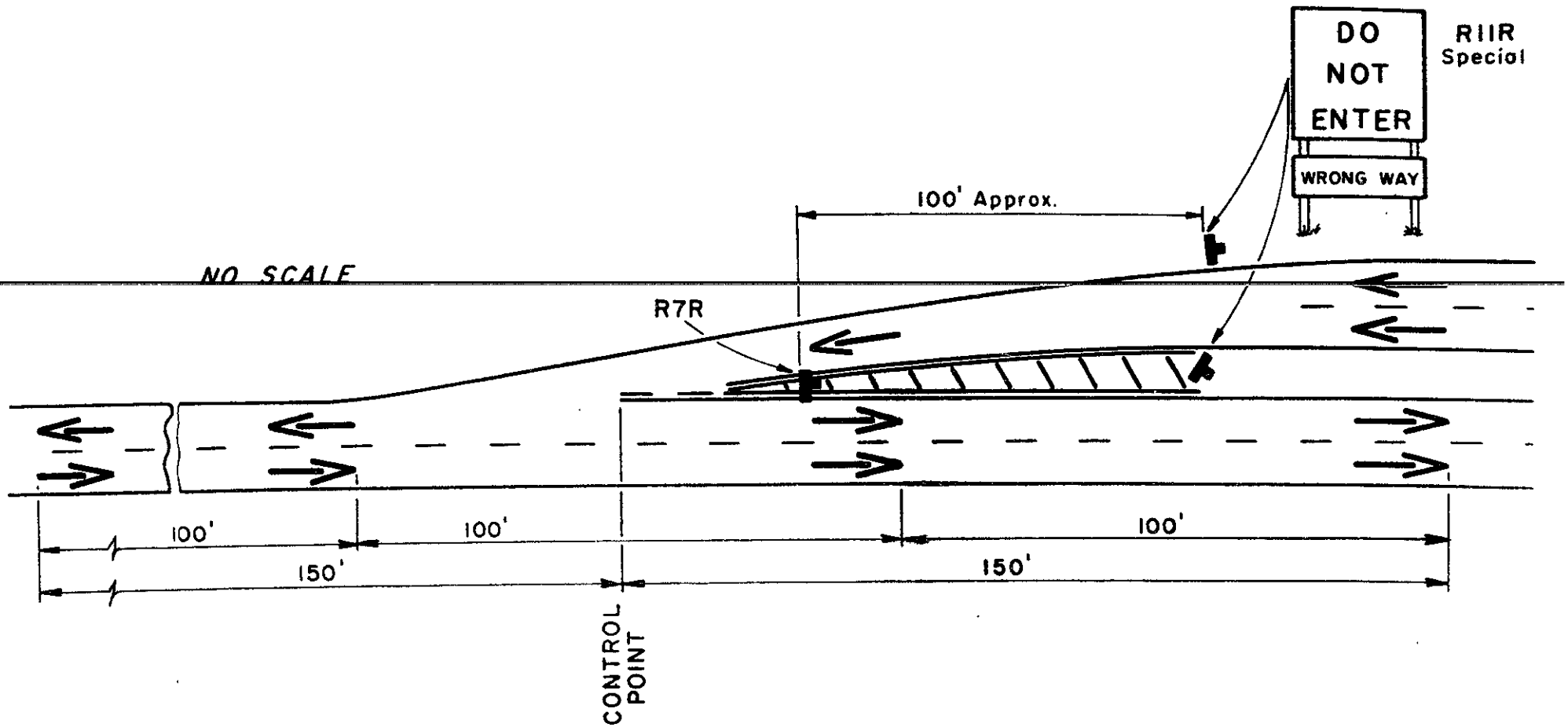
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

APPROVED:

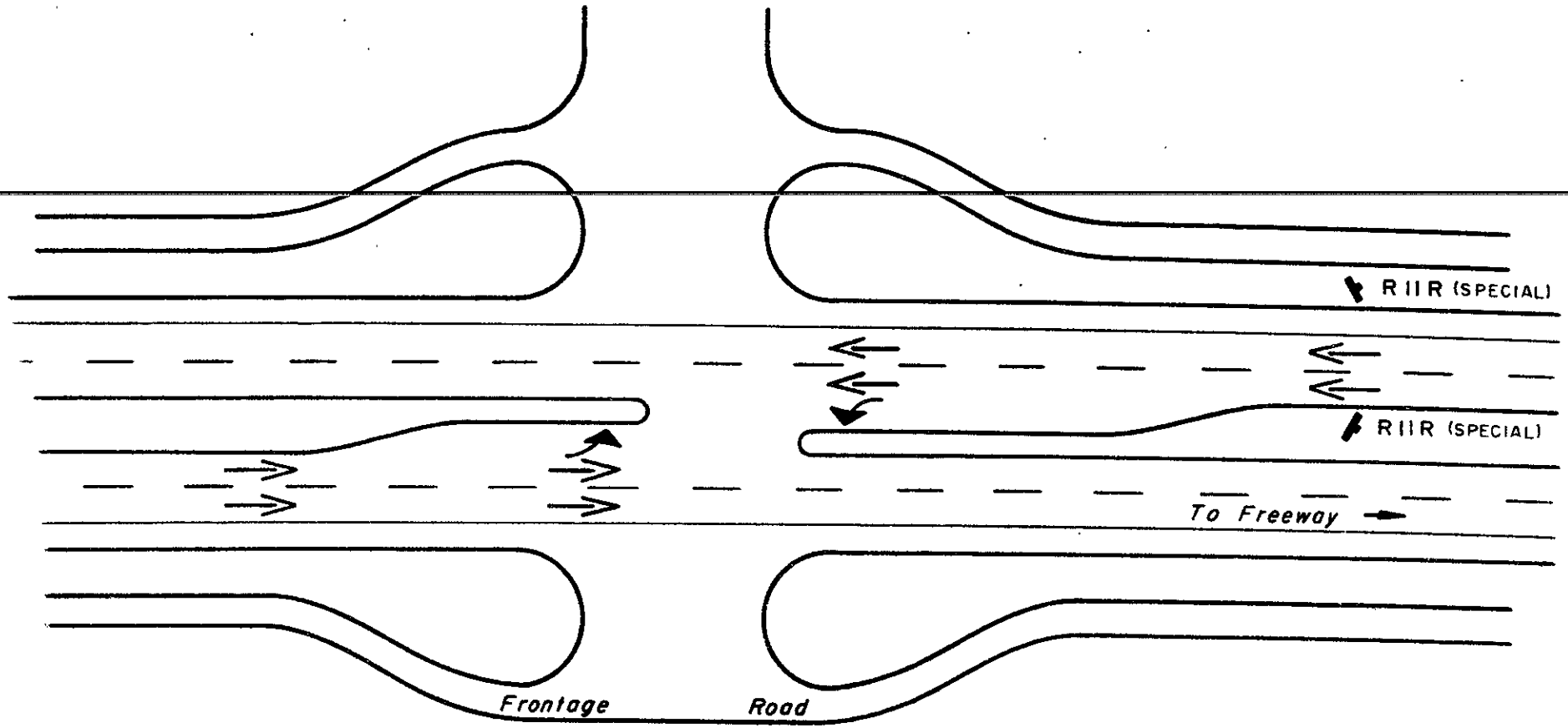
TRAFFIC ENGINEER

DATE

REVISION



SIGN and PAVEMENT ARROW
Locations for Two to Four-Lane Transitions



NOTE
Use blinders on sign or orient so sign will not be visible to right-way drivers.

LEGEND

New pavement arrow

M.U.T.C.D. standard left turn arrow

Pavement Arrow and
Special R11R Placement
EXPRESSWAY TO FREEWAY